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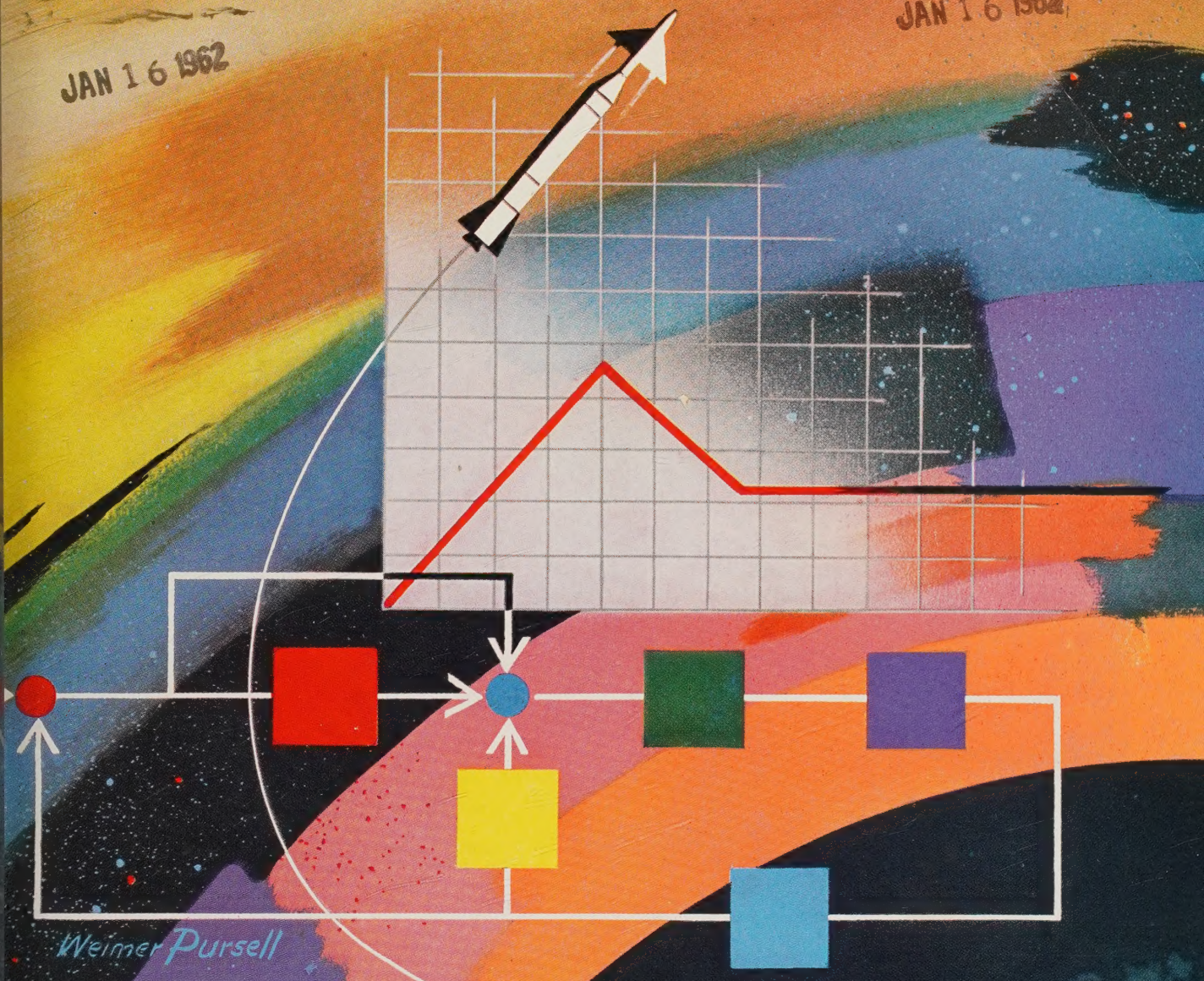

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Vostok I Analysis / Beryllium for Structures / Fiber Optics

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No. 1 on Reader Service Card

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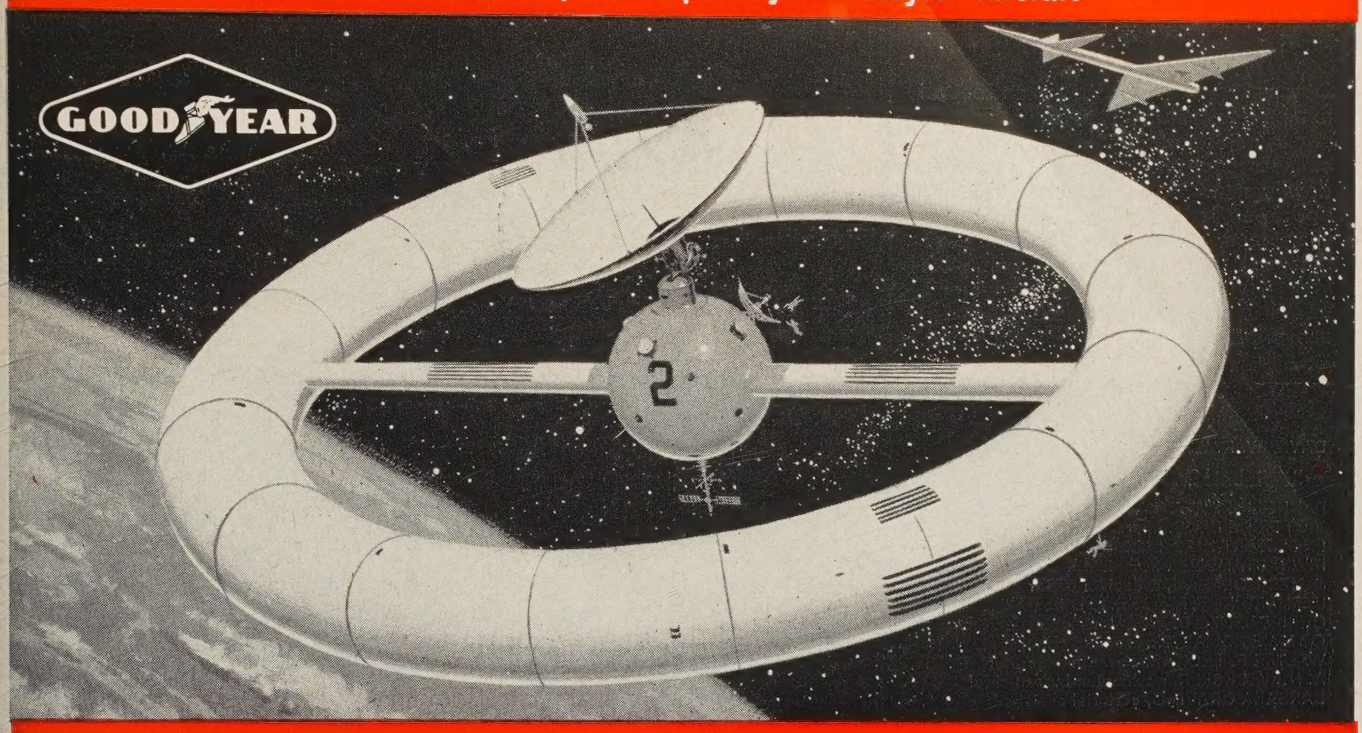

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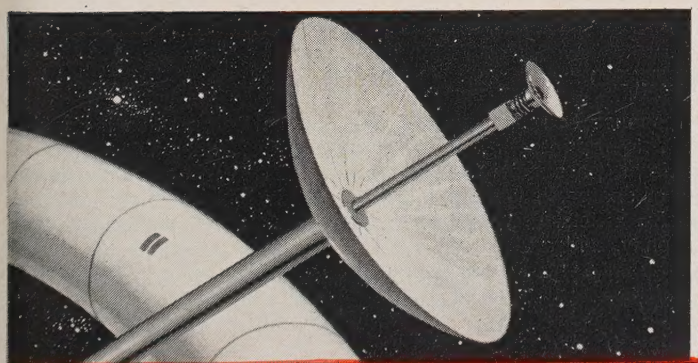

Solar concentrator with new "trumpet" condenser expands to 44½-ft. diameter. Design has been thoroughly tested for space environment.

Ballute recovery system, tested and proven in flight test, provides variable controlled drag for re-entry vehicle.

Space/Aeronautics is written and edited to meet the technical information needs of engineers and scientists in all phases of aerospace management, research, development, and production. To this audience it is distributed on a no-charge, controlled basis. If you believe that you qualify as a Space/Aeronautics reader but are not receiving your own copy of the magazine, please fill out the subscription card inside the front cover.

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REPRINTS

In response to numerous inquiries, Space/Aeronautics is making available reprints of "Communications Satellites: The Technical Problems," a special S/A survey printed in the September issue free of charge. If you missed reading this important and comprehensive article, or would like extra copies send your name, title company, and address to:

Space/Aeronautics, Reprint Department, 205 E. 42nd St., New York 17, New York.

	SYSTEMS ENGINEERING	STRUCTURES	PROPULSION	ELECTRONICS	ACCESSORY SYSTEMS	MATERIALS	PRODUCTION ENGINEERING	TESTING	DYNAMICS	SUPPORT	HUMAN FACTORS
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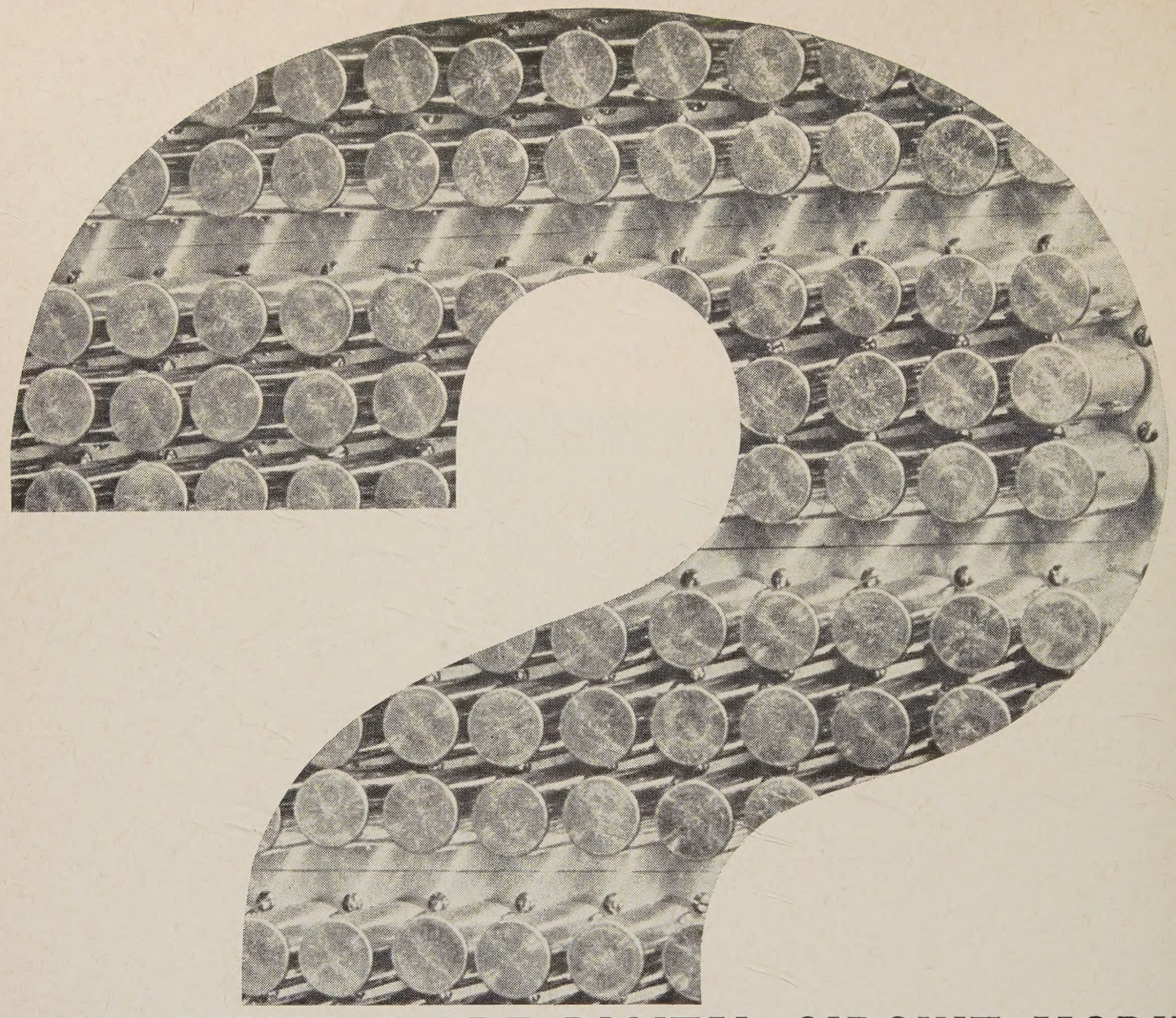
COMING

In many cases, the only tangible thing you have left after a missile or space flight test is a few thousand feet of magnetic tape. The need for accuracy and reliability of data records has spurred a host of improvements in tape and in the equipments that handle it, and a major survey article in next month's issue will give you the low-down. ■ News stories about space flight usually concentrate either on the personality of the cosmonaut himself or on the vehicle's booster and control hardware. Perhaps because they are less romantic, life-support problems for long-term flight are covered less often. Providing food and oxygen and removing wastes, however, is just as important to the success of a mission as nuts and bolts, as an article next month will show in a report on advanced life-support systems. ■ Interested in digital computers? An article in the next issue will describe three unique designs.



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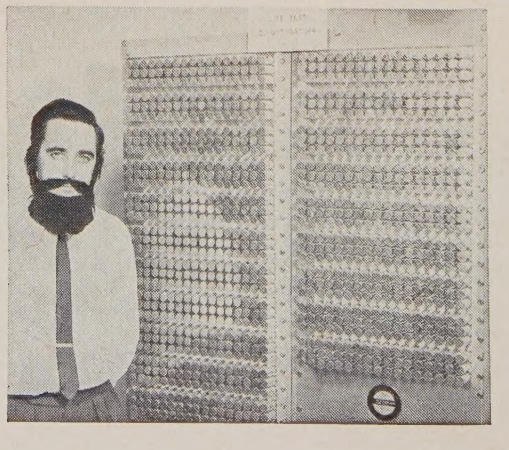

abstracts

Systems Engineering, Dynamics, Propulsion

Computer analysis reveals Vostok I design

Analysis of the orbital and re-entry parameters of the Gagarin spacecraft as well as of its thrust and accuracy requirements on the basis of known flight data.

by G. A. Cornell, R. W. Duncan, W. H. Gruber & R. J. Ritchie, Bendix

space/aeronautics 36/6 (Dec. '61) p. 54

Human Factors, Accessory Systems, Systems Engineering

Long-term orbit capsule for fifty-pound chimp

Reports on plans for orbiting and recovery of a 50-lb chimpanzee. The chimp's life cell, the overall capsule, the setup by which the animal will simulate manual pilot control operations, and the capsule's environmental system are described.

by Irwin Stambler, Associate Editor

space/areonautics 36/6 (Dec. '61) p. 77

Production Engineering

Analytic approach to stress-forming cuts time and costs

Reports on an analytical approach leading to springback-allowance equations and developed for the stretch-forming of B-38 aluminum parts. In combination with elongation control systems, it has cut production time by up to 50 per cent.

by Claude F. Morris, Jr., General Dynamics/Ft. Worth

space/aeronautics 36/6 (Dec. '61) p. 61

Electronics

Self-adaptive flight control without test signals

Reviews advantages of self-adaptive flight control systems over conventional, programed gain-change systems. Analyzes a particular configuration that uses no test signals, but instead monitors system feedback response at a point where the system's natural frequency is predominant, and describes how optimum system operation is maintained.

by Richard G. Buscher, General Electric

space/aeronautics 36/6 (Dec. '61) p. 102

Structures

Beryllium for aerospace structures

Summarizes in graphic form the results to date of a comprehensive evaluation of beryllium as an aerospace structural material. The properties and performance of block and sheet beryllium are analyzed in tables and drawings.

by L. A. Riedinger, Lockheed Missiles & Space

space/aeronautics 36/6 (Dec. '61) p. 64

Electronics

Principles of fiber optics

First article of a two-part state-of-the-art series on fiber optics in aerospace electronics. Reviews the relationship between fiber geometry and transmission path as well as cladding requirements and the various forms of fiber-optical mosaics.

by J. W. Hicks & P. Kiritsy, Mosaic Fabrications

space/aeronautics 36/6 (Dec. '61) p. 109

Systems Engineering, Structures, Propulsion, Accessory Systems

Blue Streak now slated for satellite launches

A progress report, covering structure, propulsion system, and major subsystems, on the British Blue Streak, Europe's most ambitious spacecraft program to date. The Blue Streak will be used as the first stage of a satellite launcher.

by Christopher Dawson, Associate Editor

space/aeronautics 36/6 (Dec. '61) p. 69

Electronics

Applying fiber optics

Second article of a two-part state-of-the-art series on fiber optics in aerospace electronics. Reviews the effects of fiber design on performance, covering resolution and depth of focus vs physical dimensions as well as curved fiber-optical plates.

by W. B. Krakows & A. M. Baker, Chicago Aerial Industries

space/aeronautics 36/6 (Dec. '61) p. 117

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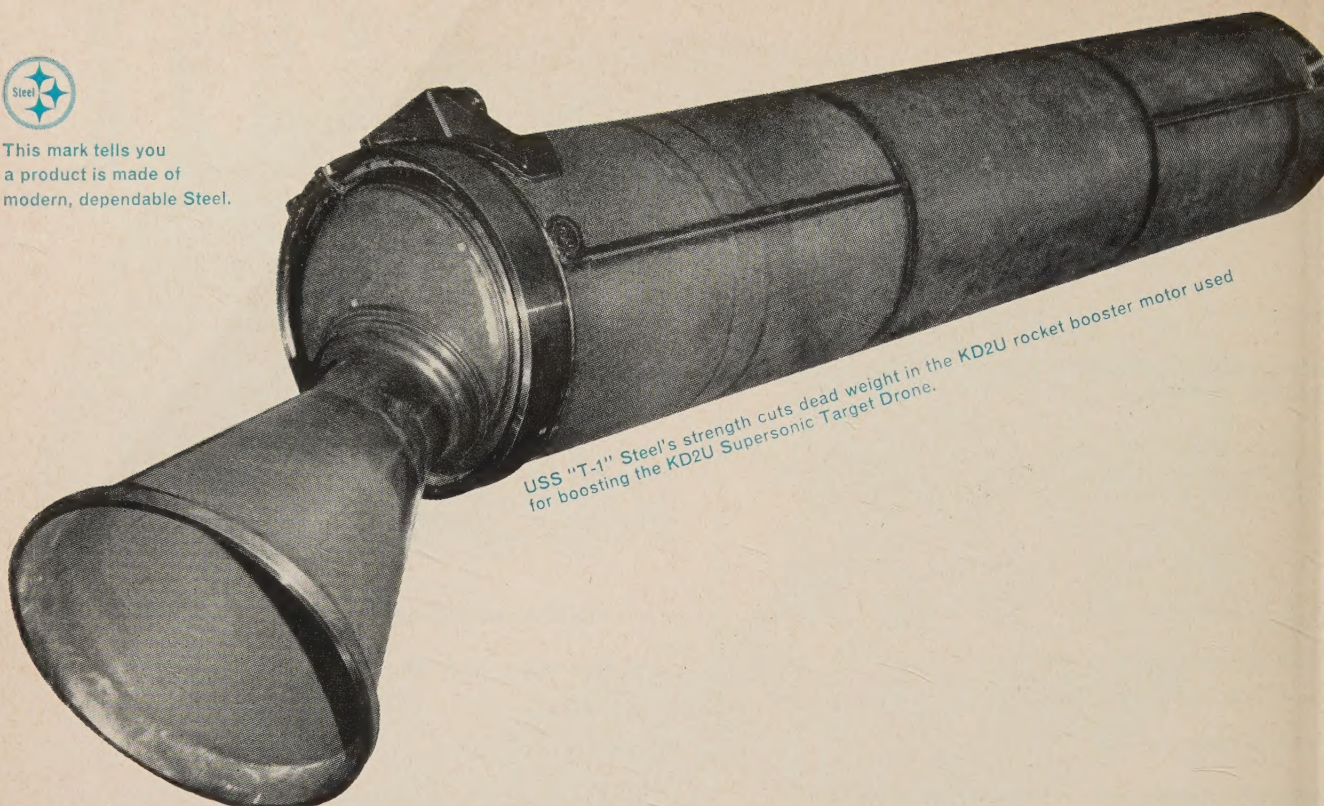
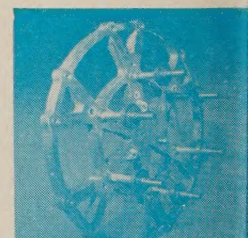
a product is made of
modern, dependable Steel.



USS "T-1" Steel's strength cuts dead weight in the KD2U rocket booster motor used for boosting the KD2U Supersonic Target Drone.

℞ for the most important 4 seconds in a rocket motor's life... USS "T-1" Stee

When the KD2U Drone Booster Rocket Motor blasts off to boost a missile or plane, its firing lasts for only 4 seconds. Then it goes into free fall. To get maximum speed, weight had to be kept to a minimum without sacrifice of strength. USS "T-1" Constructional Alloy Steel filled the bill. "T-1" Steel has three times the yield strength of carbon steel. It delivers a high minimum yield strength of 100,000 psi. This permitted the missile motor case to be fabricated from plates only 0.313 inches thick. If steel with less strength had been used, weight of the motor case would have been greatly increased. Heavier casings would require more thrust and more fuel. Low cost fabrication. Intercontinental Manufacturing Company, Inc., of Garland, Texas, a wholly owned subsidiary of The Lionel Corporation, builds the KD2U Metal Booster case for North American Aviation's Rocketdyne Divisio They found that USS "T-1" Steel could be readily shaped, forged and machined. It could be weld without impairing mechanical properties and no stress relieving was required. All these factors help to reduce costs. For more information on USS "T-1" brand and other aircraft quality steels, wri United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. USS and "T-1" are regi tered trademarks.



Bulkheads to hold the so fuel in place are flame-cut fr "T-1" Steel and inserted in t ends and center of the ca

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USS United States Ste

Vote of confidence for supervisors

THIS MONTH'S Readers' Round Table on supervisors is practically overflowing with good will, and it can't be just holiday spirit, because the questionnaires went out in October. Over two-thirds of the 69 engineers on the panel rate their supervisors' all-over performance "excellent" or "good."

Some of their comments wax positively lyrical: "Best man I ever worked for—perceptive, understanding, competent, vigorous . . ." "He is too good to be true—how can he be cured to act like the rest of the rats?" "He is dynamic, can out-engineer most of his men, and has excellent leadership qualities (a rare bird) . . ."

Many others are only slightly more restrained: "He is a very competent engineer and handles men well . . ." "Very fair, respected in and out of group, technically and personally . . ." "Nice, honest man you come to regard as a friend . . ." There is, however, a vigorous minority report, best represented by the engineer who says that his supervisor's worst fault is "his work, which is little," and his worst problem the fact that "the people who are capable of doing his work are leaving fast."

The area in which the largest number of engineers

Q. Does your supervisor's job involve actual engineering, or is it wholly supervisory?
A. Involves engineering: 50; Wholly Supervisory: 19

Q. How do you rate his all-over job performance?
A. Excellent: 14; Good: 33; Fair: 16; Poor: 4; Very Poor: 2

Q. How do you feel about the degree of supervision he exercises over your work?
A. Fair and Reasonable: 55; Excessive: 5; Too Little: 10

Q. Does he accept responsibility for his mistakes or pass the buck?
A. Accepts Responsibility: 55; Passes the Buck: 9

Q. Does he do his best for your department or group when problems arise with, or requests must be made to, higher-ups or company management?
A. Yes: 49; No: 17

Q. Does he speak up to management when he disagrees with company policy or requirements?
A. Yes: 43; No: 20

Q. Does he permit you to do so?
A. Yes: 44; No: 21

Q. Does he make an effort to keep paperwork to a minimum?
A. Yes: 44; No: 24

Q. Does he give credit for outstanding work or take the credit himself?
A. Gives Credit: 56; Takes It Himself: 8

Q. Does he make recommendations on raises for your group?
A. Yes: 62; No: 7

Q. If so, do you think his recommendations are fair?
A. Yes: 50; No: 8

Q. Do you think he pushes hard enough for what he thinks you deserve?
A. Yes: 30; No: 18

How do you rate him specifically?

	Excellent	Good	Fair	Poor	Very Poor
Education	21	38	8	1	1
Professional Experience	23	30	13	1	2
Technical Ability	27	23	12	5	2
Executive Ability	10	17	27	9	6
Personal Qualities	26	24	14	4	1

■ Yesterday, the Grand Central Rocket Company was a partially-owned subsidiary of Lockheed. Now GCR is wholly owned, and it has a new name:

LOCKHEED PROPULSION COMPANY

■ The scientists of this new Lockheed company are among the most talented in the free world. Their facilities are modern and advanced—and getting more so every day. ■ You'll be hearing much more about this growing Space Age force. ■ Lockheed Propulsion Company, Redlands, Calif.

No. 2 on Reader Service Card

What Else They Said

About Supervisors They Like

"He almost bends over backwards to be fair about mistakes."

"He works 60 hours a week, but does not demand this of anyone else."

"He is excellent at going to bat for his men and cutting red tape."

"He readily accepts responsibility for his mistakes and often for those of others."

"He is extremely careful about giving credit where credit is due—possibly even overcareful, at least as far as I am concerned."

About Supervisors They Don't Like

"Prefers to find a way to bypass or circumvent company policies rather than change them . . . too often he expects me to stick my neck out rather than he his."

"He hasn't the faintest idea of my capabilities or what I am doing."

"He leaves no room for self-expression. He doesn't appreciate the fact that more than one method will do the job."

"Although he claims to be a graduate I.E., he displays no technical approach or know-how on even the smallest problems. Has to be carried by the men he 'supervises.'"

About Supervisors' Worst Faults

"Crude and blunt mannerisms with people below his rank."

"Fear of his job, fear of people, fear of criticism."

consider their supervisors relatively weak is executive ability. Only about half as many men give "good" or "excellent" marks in this category as in the four others they were asked to consider—education, professional experience, technical ability, and personal qualities.

What's a good executive? The term "executive ability," of course, covers a multitude of virtues. The ones the Readers' Round Table engineers seem to value most highly in their supervisors—and find missing most often —are skill, sympathy, and firmness in dealing with people, both subordinates and higher-ups. Criticisms of supervisors' organizational efficiency—in handling the departmental workload, for instance, or coping with routine paperwork—are relatively few and mild. And only a handful of men—the six who give "poor" and "very poor" ratings and two or three others—have any complaints about their supervisors' integrity and fairness.

The panel members want and appreciate leadership: "He pushes me where I need pushing . . ." "He is on top of everything the department does . . ." "Expects good performance and provides the supervision necessary to get it . . ." Only five men say they feel over-supervised, and only two think their supervisors drive them too hard.

He talks things over Engineers clearly want easy communication with their supervisors. In answer to the question, "What is his worst fault?", a dozen men mentioned either inaccessibility or inarticulateness: "Doesn't have the time to talk over your problems . . ." "Lacks the ability to explain and allocate new work . . ." "Generally not available for consultation . . ." "Comes to talk only as a last resort to get the job done . . ." "Seeming lack of interest in our welfare . . ." "Can't express his plans for an overall task . . ." (Three men said that their supervisors' worst fault was "talking too much." Four mentioned tactlessness and bad temper. And five could think of nothing worse than "too easy-going.")

Engineers also want their supervisors to go to bat for their departments when problems arise with higher management, and resent it when they don't. Virtually all the men who give all-over performance ratings of less than "good" have acid comments to make about timidity or toadying in dealings with higher-ups: "He does try to aid in obvious problems, such as correcting the spelling of the sign on the door . . ." "There is no such thing as upsetting the higher-ups; when they scowl, he gets upset . . ." "Cautious of politically impeding own advancement; 'sells' company policy to us, no matter how incorrect . . ."

The question, "What do you think is your supervisor's greatest problem?" drew a dozen mentions of "company red tape . . ." "management . . ." "lack of management support . . ." "Convincing upper management of the needs of the group."

"Too technical for supervision"? Several panel members say, in effect, that their supervisors are good engineers who should have stuck to straight engineering: "He tries to do all the engineering and gives human relations a secondary place . . ." "Technically excellent but administratively poor . . ." "Too technical for supervision . . ."

The general feeling seems to be that it's fine for a supervisor to be a brilliant technical man, *if* he is also a leader and organizer and *if* he is able to subordinate his own enthusiasm for engineering to the job of running the department and getting the best out of his men. (Several men make criticisms like: "Tries to do too much himself . . ." "Insists on having his own way in design . . ." "Expects others to use his approach rather than their own . . .")

On the other hand, a pretty high degree of technical competence is essential—just ask the men whose supervisors don't have it. "He does not know the job, therefore how can he supervise?" says one engineer who gives a "very poor" rating.

Men who rated their supervisors' all-over performance as less than "good" got an extra question to answer: "How do you think he got his job?" Four mention outstanding engineering ability without executive ability to match. Successful politicking ("He is a very likable person, and works very hard to establish social contacts with higher management")—also got four mentions, and personal friendships ("He was a friend of the chief engineer when both were at another plant") got three. The most popular explanation—given six times—was simply "seniority."

BOOKS

Space dynamics text doubles as reference

"Introduction to Space Dynamics,"
by William T. Thomson, Wiley, $11.50

THIS TIMELY book interestingly and clearly presents the areas of classical dynamics that find direct application in rocketry and space flight. Written on the senior or first-year-graduate level; it will be welcomed either as text or reference work. Chapters Four through Eight should prove of particular interest to the practicing engineer.

After an introductory chapter dealing with the laws of motion and vector relationships, the author develops the kinematics of motion with respect to fixed and moving coordinate systems, and the transformation of displacements and velocities from one system to another. Next he discusses orbital mechanics in considerable detail. The general orbital equation and velocity are found as solutions to the central force problem of particle dynamics. Orbital geometry is developed, and its parameters related to rocket burnout conditions. This is followed by a presentation of the requirements for transfer between various types of orbits and for orbital stability. The problem of satellite rendezvous is considered for the case of two vehicles on the same circular orbit, two vehicles on the same eliptic orbit, and two vehicles in noncoplanar orbits. Ballistic trajectories are discussed in terms of previously developed orbital parameters. Finally, orbital precession due to the earth's oblateness is considered.

Chapters Five and Six deal with the mechanics of the gyroscope, starting with a general development of Euler's moment equations for principal and non-principal body axes. An explicit solution is given for bodies of revolution free from externally applied moments. The solution for bodies with unequal principal moments of inertia is developed in terms of elliptic integrals, and is followed by a discussion of the stability of such motion. The general theory of the symmetric gyro is presented together with the special case of steady precession, and then a brief study of the precession and nutation of the earth's polar axis. Small perturbation techniques, of paramount importance in gyro instrument applications, are used to arrive at gyro oscillatory characteristics. These are applied to the case of oscillations about gimbal axes and the oscillations of a gyro compass. The equations and principles of rate gyros and integrating gyros, as distinct from attitude gyros, are presented.

Chapter Seven is devoted to the dynamics of vehicle motion. Beginning with the general equations of motion in body coordinates, the author considers the problem of thrust misalignment on a spinning rocket and refers the solution to inertial as well as body axes. There follows an investigation of the effect of small inertial deviations from a body of revolution, satellite de-spinning, attitude drift, mass variations, jet damping and angle of attack, and finally a section dealing with the general motion of spinning rockets with variable mass and configuration.

In Chapter Eight, the author is concerned with the performance of single-stage rockets, the optimization of multi-stage rockets and of trajectories, and optimal propellant usage. The results of these studies are limited by the exclusion of all aerodynamic forces from the equations of motion.

The concluding chapter is devoted mainly to a development of the principles of classical mechanics. There is a brief introduction to general missile dynamic analysis, taking into consideration elastic degrees of freedom and engine gimbaling. The effects of fuel sloshing and control system interaction, however, are omitted.

Henry G. Mayer, Head, Dynamics Section, Engineering Div., Aerospace Corp.

Theory of Inertial Guidance, by C. L. McClure. Aim of this book is to combine a review of the classical concepts of Newtonian dynamics with discussion of the latest topics relating to schematic design, error analysis and functional appraisal. The author is an advisory mathematician for IBM. Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. $12.

Instrumentation and High Speed Photography Vol. 1, Series II. Subjects include light sources; optics and visibility; cameras and accessories; television systems in instrumentation; and applications in military and industrial testing. The work also has an author and title index for vols 1-6, series I. Society of Motion Picture and Television Engineers, 55 W. 42nd St., New York 36, N.Y. $4.00.

Missile Aerodynamics, by Jack N. Nielsen. One of the more comprehensive compilations of present day missile aerodynamics is given in this book. Sections include recent work in wing-body interference, wing-body-tail interference, drag of complete missiles and stability derivatives of complete missiles. McGraw-Hill Book Co., 330 W. 42nd St., New York 36, N.Y. $12.50.

International Missile and Spacecraft Guide, by F. E. Ordway III and R. C. Wakeford. This massive (411 pp.) encyclopedia presents current data, pictures, etc., on missiles and spacecraft throughout the world. Besides short descriptions of individual vehicles, the book also includes a directory of government agencies and companies working in various segments of the field. McGraw-Hill Book Co., 330 W. 42nd St., New York 36, N.Y. $25.

Russia's Rockets and Missiles, by Albert Parry. Written for the layman, this is an evaluation of the USSR's missile capabilities by Prof. Parry, who founded the department of Russian studies at Colgate Univ. McGraw-Hill Book Div., 330 West 42nd St., New York 36, N.Y. $4.95.

Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, by E. M. Emme. U.S. Government Printing Office, Washington 25, D.C. $1.75.

Metal Reinforced Ceramics, by J. R. Tinklepaugh et. al., Office of Technical Services, Washington, D.C. $2.25 (OTS 171550).

Shock and Vibration in Linear Systems, by P. A. Crafton. Harper & Bros., 49 E. 33rd St., New York, N.Y. $10.00.

SUBMARINERS' CLASSROOM

his rolling cab is training atomic submariners. ney're learning on land what to expect deep nderseas.

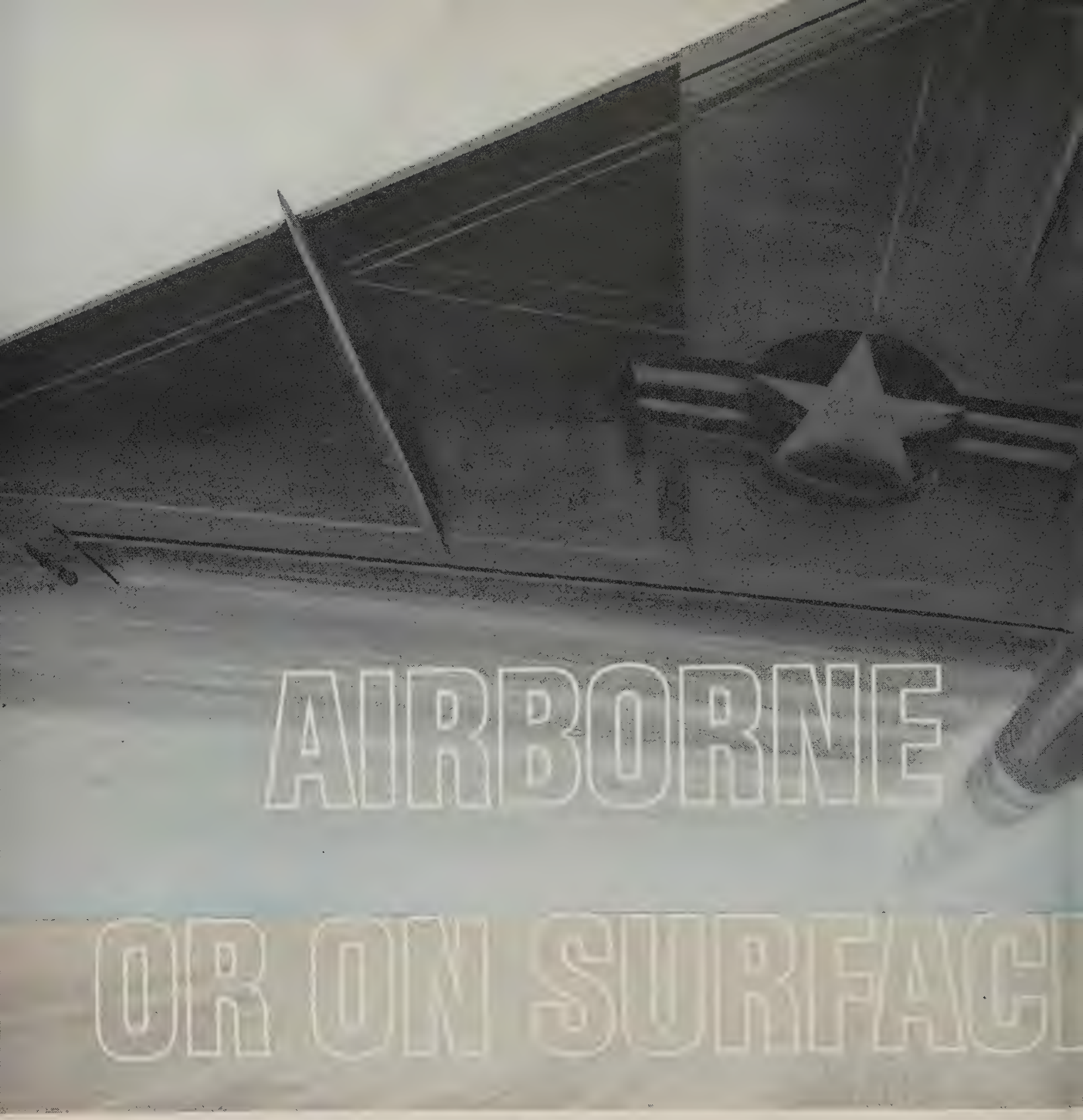
ne cab is mounted on gimbals, and simulates the ontrol center of atomic subs of the Skipjack class.

rainees sit forward. Behind them is the instructor, no feeds maneuvering and emergency problems to an analog computer. As the instruments facing e trainees record the problem, the whole cab vings into a realistic imitation of a sub underwater.

us crews are tuned to split-second response. The b simulator is in operation at the U. S. Navy Sub-arine School at New London, Conn. We designed, built and delivered it under contract to the U. S. Naval Training Device Center, Port Washington, N. Y.— ahead of schedule and within cost.

Republic produced a low cost device emphasizing versatility and low maintenance. How was it done? Credit Republic's broad experience with control systems and analog computer simulations.

REPUBLIC
AVIATION CORPORATION
FARMINGDALE, LONG ISLAND, N.Y.



CP motors drive data reco

PROBLEM

of recorder manufacturer

Obtain a motor to drive mobile recorder tape reel turntables in airborne and other portable applications. It must:

1. Operate on dc current, voltage range 22-33 volts and be reversible.
2. Be designed for continuous duty; operate at reduced voltage during 90% of its running time.
3. Develop 60 in.oz. torque at 500 rpm. at 27.5 volts.
4. Develop locked rotor torque at 120-140 in.oz. at 3.5 amps. max.
5. Withstand ambient conditions . . . temperature —55°C. to +125°C. . . . to 80,000 feet.
6. Weight not to exceed 4.5 lbs.
7. Operate at stall condition indefinitely.
8. Be able to maintain constant tape tension.

SOLUTION

by Chicago Pneumatic

CP Design Engineers, drawing on their wide experi developing special designs and types of motors, produ CP-74GE Motor. Service demands on this installation that the motor alternately act as drive or brake du recording cycle. It is ideally suited to meet the highly ized demands of tape reel drive requirements.

If you use performance and specification data on tional, fractional or integral horsepower, lightweight m aircraft, missile, space craft, naval or military applica need a copy of the CP book "ELECTRIC MOTORS AN ATORS". For your copy, write, on your letterhead, to: **Pneumatic Tool Company, 8 East 44th Street, New York**

pe at constant tension

CP-74GE Motor as furnished for driving reel tape turntables on airborne and mobile recorders.

hicago Pneumatic

N ACCESSORIES • PNEUMATIC TOOLS • ELECTRIC TOOLS • DIESEL ENGINES • ROCK DRILLS • HYDRAULIC TOOLS • VACUUM PUMPS

No. 5 on Reader Service Card

PIPELINE IN THE SKY

Riddle Airlines Inc. are flying Argosies up to 13 hours daily on the U.S.A.F. Logair routes. Logair is one of the world's largest scheduled cargo operations — an aerial pipeline for the quick supply of urgent military equipment. From coast to coast these new Armstrong Whitworth aircraft speed outsize military loads in their capacious 47 ft. long holds, over a network of routes covering the U.S.A. Daily schedules bridge more than 12,000 miles.

Soon, B.E.A. will be doing the same on their all-freight routes. Argosies will open up new high-speed supply lines for outsize cargoes between the U.K. and Europe.

An Argosy fleet means high speed delivery, reduced warehousing, less packaging, less handling time less shipping cost and — above all — unusually large freight dimensions.

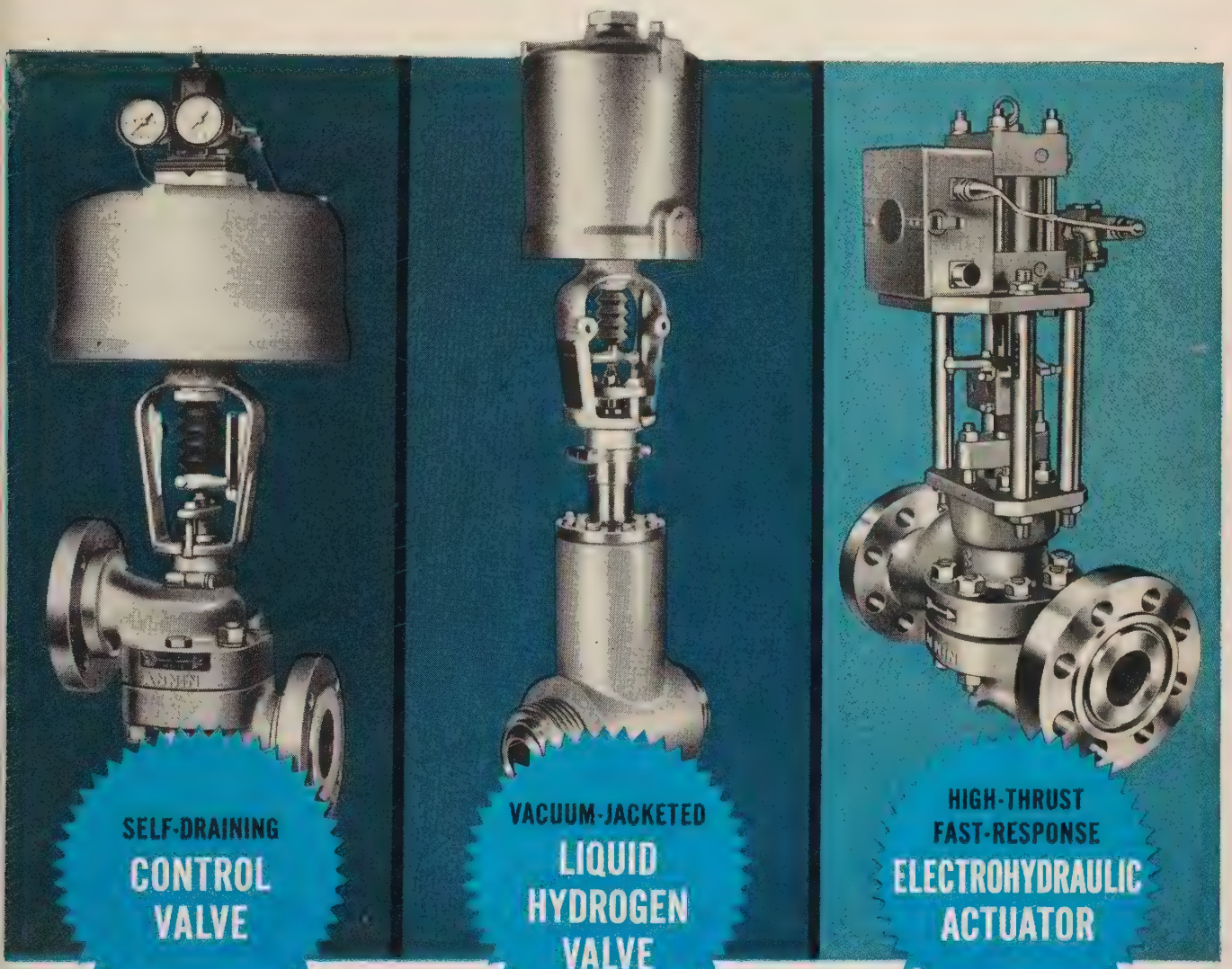
HAWKER SIDDELEY AVIATION

32, Duke Street, St. James's, London, S.W.1

No. 6 on Reader Service Card

ANNIN VALVES ...offer advanced designs for fields that are moving ahead!

MILITARY AND PROCESS CONTROL APPLICATIONS



In design and operational capability, Annin control valves begin where others leave off! The reason? Annin has always set the pace in fluid flow control ever since it pioneered split body, single seat construction, and showed control engineers how to achieve precise, positive control automatically. Typical of Annin's leadership today in fields requiring advanced design are the three new valves pictured above: Model 1900 Self-draining Control Valve, designed to handle toxic or corrosive fluids and slurries which must be flushed out of the system periodically; Model 1700 Vacuum Jacketed Cryogenic Valve, for the precise control of liquid hydrogen in missile ground support systems; and Series 20,000 Electrohydraulic Actuator, characterized by high thrust and extremely fast response, ideal for polyethylene reactor let-down valves, fuel blending systems, aero/space test stands, and with turbine by-pass valves for power plants.

Send for complete technical bulletins on these and other Annin products

ANNIN VALVES

Products that work for your profit

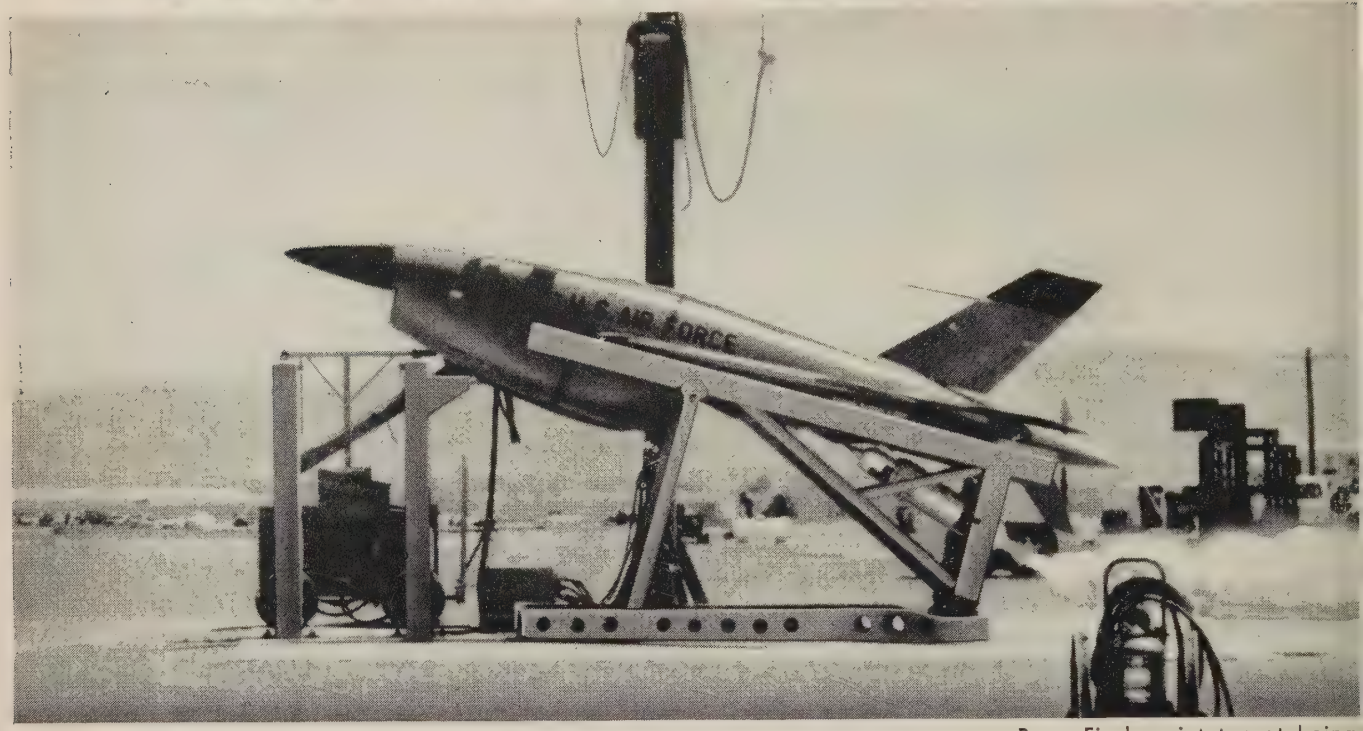
THE ANNIN COMPANY

1040 S. Vail Avenue • Montebello, California

No. 7 on Reader Service Card

SPACE AGE IMAGINATION

FRUEHAUF . . . TRUSTED NAME IN GROUND SUPPORT EQUIPMENT



Ryan Firebee jet target being launched from a Fruehauf launcher

Fruehauf—one of America's most experienced designers and producers of space-age Ground Support Equipment

Space age imagination—the ability to conceive, develop and produce Ground Support Equipment to successfully meet the challenge of tomorrow! Since the early space probes Fruehauf has been a *proven* producer of a staggering number and variety of imaginative ground handling equipment. Fruehauf's versatility ranges from transporters and containers to intricate electronic vans and launchers such as the near-zero length launcher recently produced for Ryan Firebee jet targets.

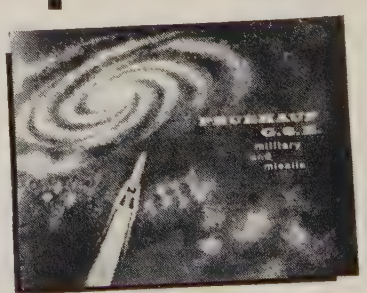
At your service are 11 strategically located Fruehauf plants across America—over 2,400,000 square feet of space available for G. S. E. production! Fruehauf personnel have worked on over 500 different types of units, many completely conceived, developed and produced by Fruehauf's highly trained military oriented specialists, men with years of *proven* experience in the field.

Fruehauf has produced Ground Support Equipment for:

Atlas	Nike Ajax	Sergeant
Bomarc	Nike Hercules	Hawk
Corporal	Nike Zeus	Jupiter
Genie	Polaris	Mace TM76
Redstone	Firebee	And many others!

Vehicles for: Army Ordnance and Corps of Engineers

PHONE OR WRITE FOR A



Fruehauf representative to give you complete details, or write for FRUEHAUF G.S.E., Fruehauf's latest 4-color military and missile brochure.

FRUEHAUF TRAILER COMPANY

Plants in the East and West

MILITARY EQUIPMENT DIVISION — DETROIT 32, MICH.

MISSILE PRODUCTS DIVISION — LOS ANGELES 58, CALIF.

No. 8 on Reader Service Card

Check Inquiry Form on Page 131

SCIENTIST-MANAGER PhD Physics

Applications of Ion, Arc Jet, MHD and Other Advance Engines to SPACE PROPULSION SYSTEMS

One of the most challenging assignments in space technology—the application of very advanced engines to provide capability for space maneuver and deep space propulsion. This scientist will lead a small group of specialists. Requires doctoral degree in Physics and minimum of 8 years applicable experience, with 2-3 of these in electric propulsion R&D.

Ⓐ

CONSULTANT Space Structures

Sought: A high calibre engineer/scientist to advise, recommend and implement long range programs in space structures . . . able to contribute creatively well beyond current state of the art. Advanced degree preferred. Ⓑ

ANTENNA & PROPAGATION ENGINEERS:

To carry on theoretical & experimental studies of advanced nature for all radio frequency bands. EE's. (Advanced degree preferred.) Minimum of 6 years experience. Ⓒ

Analog Computer Specialists

To plan sequence of computer operations and determine circuitry for engineering problems connected with research, development and design of advanced satellite, spacecraft and missile systems. Set up and operate computer programs in a growing analog facility equipped with Electronic Associates and Reeves Analog Equipment, a combined Analog-Digital facility, and passive element analog computer.

Ⓓ

Diversified Assignments in Systems Engineering

SYSTEMS DESIGN
Navigation & Control Ⓕ

Challenging opportunity for engineer capable of assuming responsibility for integration, coordination and project engineering of special navigation and control systems. These include satellite attitude control, orbit control, space power. Work requires a broad background in controls; 5 or more years engineering experience; EE or ME.

SYSTEMS ANALYSIS
Varied Space Systems Ⓖ

Conduct preliminary studies to optimize space systems through subsystem trade-offs, in order to provide a balanced systems synthesis effort. Define performance requirements and specific interface relationships between sub-systems. Degree plus 4 or more years experience in systems analysis required.

RADAR SYSTEMS
Re-Entry Guidance & Space Navigation Ⓗ

Apply radar systems principles to problems of re-entry-guidance and space navigation; define parameters of the technical concept and maintain project control over full engineering effort. Requires strong background in radar systems with EE.

Senior Staff Consultant

for all System Level Experimentation in Electronics for all MSVD programs

System problems include: stabilization and attitude control of satellites and re-entry vehicles; space/ground communications; orbit navigation and control; mid-course and terminal spacecraft navigation and guidance.

An advanced degree is essential for this outstanding opportunity for high level, original work; also a substantial background in systems design. Experience in radar & communications helpful. Ⓔ

ENGINEERS & SCIENTISTS

IMMEDIATE OPENINGS AT THE MISSILE & SPACE VEHICLE DEPARTMENT

PHILADELPHIA, PENNSYLVANIA

Your inquiry is invited regarding any of the positions—encompassing more than twenty areas of space science and engineering—listed on the front and back of this page. Please use the INQUIRY CARD provided for your convenience. A prompt answer is guaranteed; your confidence will be respected.

GENERAL ELECTRIC

HUMAN FACTORS

Psychologist, MS, PhD, to solve intriguing man-in-space problems. Ⓚ

PROJECT ENGINEER

Direct advanced projects, handling program sequence and funding, interpretation of customer requirements, integration of technical areas, measurement of technical progress. *Strong administrative capabilities plus engineering background are prerequisites.*

Ⓘ

MANAGER *Advanced Space Power R&D*

Thermionics, Fuel Cells, Photovoltaics

A creative scientist with leadership abilities to guide a group responsible for advancing the state of the art in the urgent field of power, energy and storage systems for spacecraft and satellites. PhD preferred—advanced degree essential—in Physics, Chemistry or Mechanical Engineering with 8 years experience, 2-3 of these in Space Power. An outstanding opportunity for scientific achievement and personal progress.

Ⓙ

THERMO-DYNAMICS

Determine design adequacy of missiles, re-entry and space vehicles with respect to thermodynamics, heat transfer and aerodynamic heating design factors. Conduct parametric studies pertaining to configurations; performance of external protection and internal cooling systems. BSME, AE or ChE with 3-5 years experience. Ⓛ

GENERAL ELECTRIC

Vehicle Engineering . . . . . B, V
Navigation & Control . . . . . E, F, H, O
Instrumentation & Communication . . . . C, E, Q, S, T, W
Aerodynamics — Trajectories . . . . . P
Thermodynamics — Aerophysics L
Systems Analysis . . . . . G, M, N, O
Advanced Systems . . . . . F, G, H, O, M, N
Ground & Space Support . . . . . K, Y
Quality Control . . . . . R
Project Engineering I
Applied Mathematics . . . . . D, P
Producibility Engineering X
Pyrotechnics . . . . . U
Space Power & Propulsion . . . . . A, J
Analog & Digital Techniques . . . . . P, Q, S, T
Life Support . . . . . K

▶ Simply circle the appropriate letters of those positions that meet your professional interests and qualifications, fill in the questions on the back of the card and mail it to us. The card should be folded, then sealed or stapled; no postage is required. We will contact you just as soon as we have reviewed this information.

I am interested in the following position(s)

FIRST CLASS
PERMIT No. 22246
PHILADELPHIA, PA.

BUSINESS REPLY CARD
NO POSTAGE STAMP NECESSARY IF MAILED IN UNITED STATES

Postage Will Be Paid By

Mr. Frank Wendt
Missile & Space Vehicle Department
General Electric Company
3198 Chestnut Street
Philadelphia 4, Pennsylvania

ADVANCED SYSTEMS ENGINEERING

ECM SUB-SYSTEMS for Advanced Reconnaissance Vehicles. Contribute substantially to synthesis & analysis of these systems, utilizing familiarity with RF interference jammers, scanning receivers, modulation techniques, electronic decoys, etc. (M)

DATA HANDLING for Reconnaissance Command & Control Systems. Provide technical leadership in synthesis and analysis of these systems, utilizing familiarity with digital data processing, logic elements, computer programming, storage devices, displays target recognition, etc. (N)

INERTIAL NAVIGATION & CONTROL SYSTEMS for Space Vehicles. Conduct analytical studies for such systems, including mission requirements for space rendezvous and soft interplanetary landings. (Strong background in closed-loop systems.) (O)

Essentials for these positions: Physics or Electronics Degree plus a minimum of 5 years related experience.

Ground Support Electronic Systems Engineer

Design and development of ground electronic systems through the RF spectrum for application in the support systems of re-entry or space vehicles. A technical specialist position requiring a BSEE, 6 years experience and a background in such fields as communications, telemetry or radar. (Y)

Research Associate

Interplanetary and Lunar Trajectories

Conduct analytical and computer studies in applied mechanics, applied mathematics, celestial dynamics and analytical dynamics. Requires PhD in any of the following: Mathematics, Astronomy, Applied Mechanics. (P)

MANAGER

ADVANCED MISSILE & SATELLITE ELECTRONICS

A Significant Opportunity for an Engineer with a Record of Achievement. An advanced degree – MS or PhD and a minimum of 10 years applicable experience is mandatory for the highly competent and creative man required for this position. He will guide an organization responsible for the development of very advanced components for missile & satellite applications. These include incoders, command circuitry, transmitters, digital electronics, etc. (Q)

EE, ME

QUALITY CONTROL SYSTEMS ENGINEER

Review assigned systems to ensure that performance requirements and specifications are accomplished; advise design engineering; originate systems test plans; follow qualifications and acceptance of the systems. Three to ten years engineering or quality control experience required. (R)

Diversified Assignments for Design Engineers

Logic Circuit Design

Provide high level technical evaluation of digital techniques as applied to automatic programming systems for checkout equipment and airborne instrumentation. Requires EE with broad digital background from systems philosophy to final design. (S)

Digital Components & Circuits

Design and evaluate A/D and D/A converters, multiplexers, parity check generators, digital storage devices, binary counters, etc., for both airborne and ground digital equipment. EE with 2-5 years experience. (T)

PYROTECHNICS

This specialist will apply shape charges, explosive bolts, squibs and igniters to in-flight disconnects, ignition of solid propellants and separation action within re-entry and space vehicles. Requires engineering degree and 3-10 years experience. (U)

SR. STRUCTURAL DESIGN

Establish configuration D&D of re-entry vehicles, missile & space vehicles including application of new materials; determine design allowables and preliminary stress analysis. ME or AE plus 8-10 years structural design experience. (V)

TELECOMMUNICATIONS CONSULTANT

TO LEAD STUDIES AND PRELIMINARY DESIGNS INVOLVING ALL ELEMENTS OF INTERCONTINENTAL COMMUNICATIONS SYSTEMS: COMMUNICATION CENTRAL SWITCHING CENTERS, LOAD ANALYSIS, ETC. QUALIFICATIONS: PHD OR DEEP EXPERIENCE IN COMMUNICATIONS SYSTEMS SYNTHESIS AND PLANNING. THE CALIBRE MAN SOUGHT FOR THIS IMPORTANT POSITION WILL HAVE PUBLISHED PAPERS IN RELATED FIELDS. (W)

Highly Experienced PRODUCIBILITY ENGINEERS

to be responsible for the manufacturing feasibility of the satellite-re-entry vehicle design concept. They will act as consultants on manufacturing techniques to design engineering groups, carry on liaison between design and manufacturing engineers in the resolution of problems in the production phase. Their work encompasses LONG-RANGE PLANNING for new programs, schedule optimization and assurance that new advances in the state of the art are brought to bear on MSVD re-entry vehicles.

Qualifications: BS and 5-10 years combined design & manufacturing experience in aircraft structures or defense electronics. (X)

All qualified applicants will continue to receive consideration for employment without regard to race, creed, color, or national origin.

PROFESSIONAL EXPERIENCE
(Two most recent or most applicable jobs)

Company
Position
Years of experience (from)
(to) Salary
Assigned Duties

Company
Position
Years of experience (from)
(to) Salary
Assigned Duties

GENERAL ELECTRIC

PERSONAL DETAILS

Name
Home Address
City State
Telephone
U.S. Citizen Yes ☐ No ☐

Education

Undergraduate
College
Degree Year of Graduation

Graduate
College
Degree Year of Graduation

Position Objective (primary job preference, level of responsibility, salary expectations)

PLUGGING THE PROPULSION GAP

Headquarters for Glass Fiber products:
Ardmore Industrial Air Park, Ardmore, Oklahoma.

Decreased Load = Increased Thrust

With all the ballyhoo about gaps and winning races, we tend to overlook some of the less spectacular, but nonetheless, important advances we are making in the areospace industry. The development of glass fiber rocket motor cases and exit cones represents one of these little known, yet significant breakthroughs.

POXYGLAS™, as we call our filament wound glass fiber product, is the result of an extensive research program, which began in the early part of 1957. This research program culminated in a product which is capable of developing ultimate levels of 220,000 psi. in parallel stress, and 125,000 psi. in composite stress, and has specific weight of .072, or ¼ the weight of steel. With POXYGLAS, BS&B has decreased the weight of rocket motor cases, increasing their thrust capabilities.

This represents a most significant contribution to the advancement of the missile program, which includes the development of the first and second stage advanced Polaris, the first and third stage advanced Minuteman, and production of the second stage operational Polaris and third stage operational Minuteman.

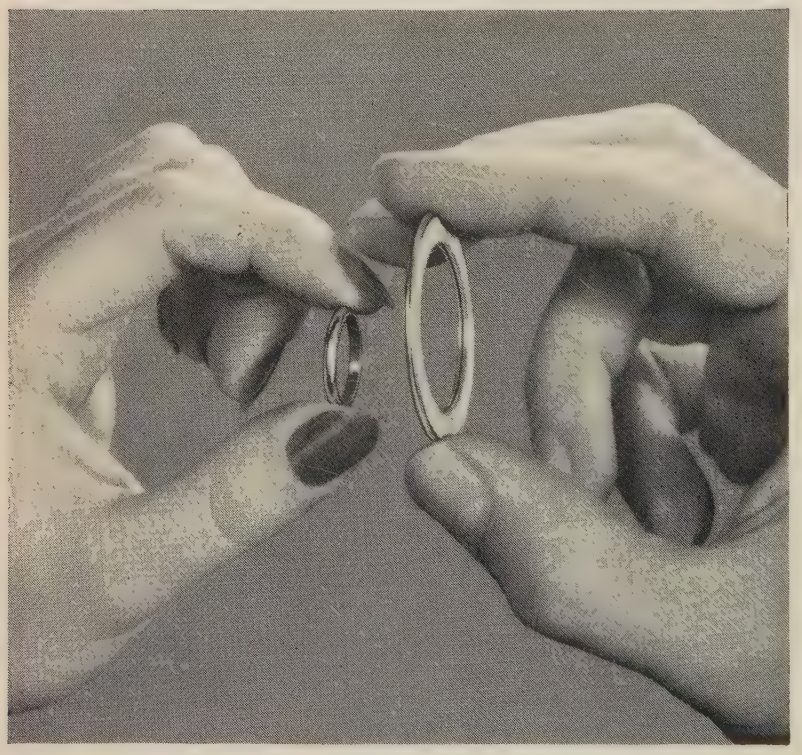
Additionally, BS&B has produced the Altair, corset molds for the Little John and Honest John projects, and a wide variety of exit cones for rocket motors.

BS&B

BLACK, SIVALLS & BRYSON

ARDMORE • KANSAS CITY • TULSA • OKLAHOMA CITY • EDMONTON • THE HAGUE

GASKETS
in Design Engineering



New, ultra-thin Garlock GUARDIAN* Gaskets solve the problem of high-temperature, limited-space sealing on missile and aircraft exhaust systems, turbines, other equipment.

At last—a spiral-wound gasket no thicker than a wedding ring! Ideal for limited space or light flange applications, this new Garlock GUARDIAN Spiral-Wound Gasket is available in thicknesses as thin as 1/16" in gaskets up to 6" I.D., maximum flange width 3/8".

Controlled density affords more positive seal. During manufacture of the new "wedding ring" GUARDIAN Gasket, the proper selected thickness of filler material and preformed metal, the number of laminations of filler and metal, and the correct tension of filler and metal while being formed into a gasket are the factors engineered to achieve proper gasket density. By controlling and varying these factors, Garlock is able to match the density to the pressure range. This built-in quality is constantly checked by a Baldwin-Lima-Hamilton compression-testing machine, thereby assuring perfect sealing regardless of different pressures and different bolt-load requirements.

High-temperature, high-strength construction. This new Garlock "wedding ring" GUARDIAN Gasket operates effectively at temperatures as high as +1900°F and pressures to 2500 p.s.i. or more. It is an excellent gasket where recycling temperatures are encountered. In the 700°F to 1200°F range, Garlock uses a compressed asbestos filler with stainless steel plies; in the 1200°F to 1900°F range, a ceramic filler is used with several different types of metal plies, depending on customer preference. The ceramic is non-flammable, completely inorganic, and an outstanding chemical insulator. It resists mold, mildew, and aging, thereby allowing indefinite shelf life.

Where service is severe and space at a premium, use new Garlock "wedding ring" GUARDIAN Gaskets. They may be the answer to your sealing problems. Find out more from your Garlock representative. Call him at the nearest of the 26 Garlock sales offices and warehouses throughout the U. S. and Canada. Or write Garlock Inc., Palmyra, N. Y.

GARLOCK

Canadian Div.: Garlock of Canada Ltd.

Plastics Div.: United States Gasket Co.

Order from the Garlock 2,000... two thousand different styles of Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastic Products.

*Registered Trademark

No. 10 on Reader Service Card

Insulation news from Johns-Manville

Now Min-K® is flexible!

THE INSULATION WITH A LOWER CONDUCTIVITY THAN STILL AIR IS NOW AVAILABLE IN BLANKET AND TAPE FORMS FOR UNLIMITED NEW APPLICATIONS

Min-K, the unique insulating material developed and produced by Johns-Manville, now has an added quality . . . flexibility! Min-K is a new concept in missile insulation. The higher it flies, the better it insulates. Min-K's thermal conductivity drops as atmospheric pressure decreases. Its superior performance has been proved in hundreds of operational U. S. missiles.

New Flexible Min-K offers many special advantages. For example, it is the ideal way to lower prototype costs. You can test performance without the expense of special tooling. The flexible blankets lend themselves to bonding, lamination with reinforced plastics, service coatings and as a component of insulation systems. Further, Min-K can be tailor-made to wrap around a cylinder, cone or other geometric shape. And, it is also available in 1½" and 2" tapes for spiral winding on a duct or pipe.

Because of the added quality of flexibility, Min-K's unique insulating characteristics now can be used in virtually unlimited new applications. For full details on Flexible Min-K, Min-K and other J-M aviation insulations, write Johns-Manville, Box 14, New York 16, New York. In Canada: Port Credit, Ontario. Cable address: Johnmanvil.

JOHNS-MANVILLE

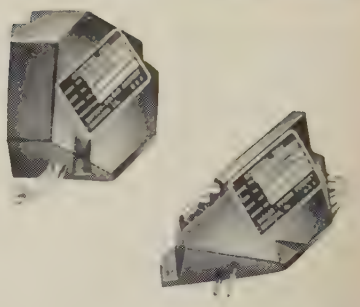
JM PRODUCTS

No. 11 on Reader Service Card

how Barber-Colman engineers meet critical tolerance and envelope challenge of Titan temperature control project

Assignment to Barber-Colman Company from Air Force TITAN associate contractor, AC Spark Plug, Milwaukee: Take one part of the Air Force TITAN guidance platform and develop a complete temperature control system that will fit into the odd-shaped, very limited space available. Hold temperature to the exceptionally close tolerances specified. *Result:* A precision Barber-Colman temperature control system incorporating an ingeniously formed set of compact control boxes and sensing element (right) which control temperature of the internal structure to within a few hundredths of one degree. Unusual assignments like this are the kind of challenge that Barber-Colman people like to accept. For help with your temperature control problems consult the Barber-Colman engineering sales office nearest you: Baltimore, Boston, Fort Worth, Los Angeles, Montreal, New York, Rockford, Seattle.

FORM-FITTING TEMPERATURE CONTROL BOXES FIT SMALL, IRREGULAR SPACE



Related control boxes and sensing element for Air Force TITAN guidance platform temperature control application.

THE MARK OF QUALITY

BARBER COLMAN

BARBER-COLMAN COMPANY

DEPT. X, 1423 ROCK STREET, ROCKFORD, ILLINOIS

AIRCRAFT AND MISSILE PRODUCTS: AIR VALVES, ELECTROMECHANICAL ACTUATORS, TEMPERATURE CONTROL SYSTEMS, POSITIONING SYSTEMS, TRANSDUCERS AND THERMOSTATS, SPECIAL GROUND TEST EQUIPMENT

No. 12 on Reader Service Card

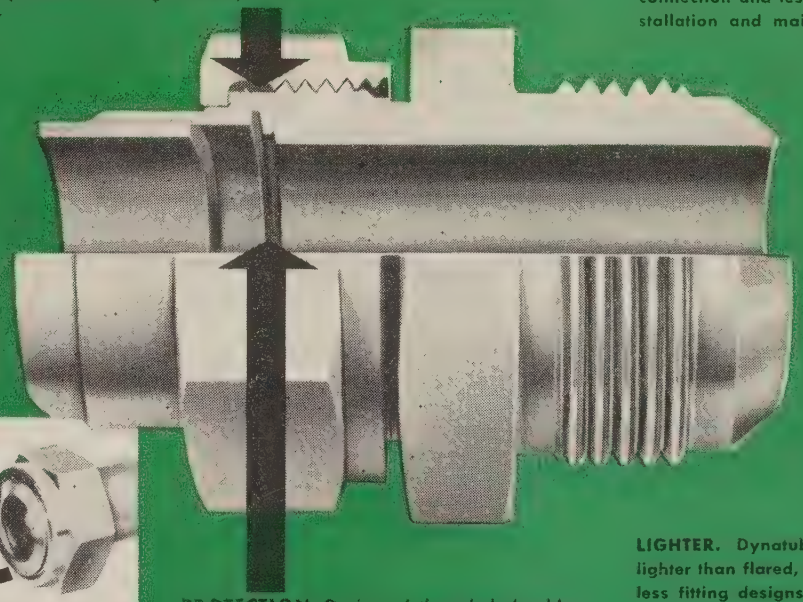
Leakproof Coupling
for High-Performance Systems

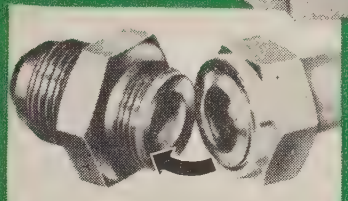
DYNATUBE*

A NEW DYNAMICALLY SEALED TUBE CONNECTION BY RESISTOFLEX

DYNAMIC SEALING. Dynatube design incorporates a dynamic seal whose efficiency increases with elevated pressures—without need for extreme machine finish such as that required by metallic O-ring devices, etc.

SPACE SAVER. Smaller envelope of Dynatube means easier wrench access, less distance across hex corners, less protrusion of total connection and less clearance needed for installation and maintenance in critical uses.





METAL-TO-METAL contact forms full seal at torque range between 26 foot-pounds and 200 foot-pounds, compared with 7 foot-pound range (110 to 117 fp) for flared fittings in the —16 size.

PROTECTION. Design of threaded shoulder permits the nut to act as a protective cover for the tube end, minimizing possibility of damage to seal. Dynatube is considerably stronger than standard AN or MS fittings.

LIGHTER. Dynatube fittings are markedly lighter than flared, modified flared and flareless fitting designs . . . offering up to 74% weight savings over flared fittings, combined with zero leakage because of pre-determined stress level at seal.

*Dynatube is a Resistoflex trademark. U.S. and Foreign patents applied for.

Dynatube, another *first* by Resistoflex, is an all-new concept in metal rigid tube connections . . . providing a superior seal for high performance hydraulic, pneumatic, fuel and oxidizer systems.

Dynatube provides maximum performance because

- The seal is controlled by precision dimensions built into the fitting
- The fitting design is based on pre-determined stress level at the sealing point
- Torque range is extremely wide

Dependence on surface finishes of sealing seats, concentricity of AN and MS screw machine parts and torque application is completely eliminated with Dynatube.

Severe temperature cycling does not affect the Dynatube seal, which maintains its reliability up to 700° F. and higher, depending on application. Not sensitive to torque degradation, Dynatube has a smaller envelope and is lighter and stronger than corresponding AN or MS fittings. Meets or exceeds all performance requirements of proposed MIL-F-18280B.

Here is the answer to your tube sealing problems. Ask your Resistoflex field engineer about Dynatube, or write to Resistoflex, Roseland, N. J. for Bulletin DY-1.

RESISTOFLEX

RELIABILITY

COMPLETE SYSTEMS FOR CORROSIVE SERVICE

No. 13 on Reader Service Card

Above: Actual Photograph of Grand Central Rocket Co's. ten-foot diameter BIG BOOSTER.

Below: Ten inch diameter RETRO-ROCKET.

Both are in current manufacture at EXCELCO.

DIVERSiTY

EXCELCO has the Diversity of equipment, experience and skills to produce rocket engines that range from a mere ten inches to a giant ten feet in diameter.

The BIG BOOSTER Rocket Engine illustrated is the western world's largest solid fuel rocket engine. It was built by EXCELCO for the Grand Central Rocket Co., prime contractor on the Air Force program, directed toward rocket motors with multi-million-pound thrusts.

The in-between range of rocket engines also produced by EXCELCO include RV-A-10, Sergeant, Air Force-ReEntry X-17, Polaris-ReEntry X-36, Jupiter Jr., Jupiter Sr., Polaris O, Polaris A, Polaris AIX, Polaris A2-MOD 1-2-3, Nike Hercules, Nike Zeus, Minuteman, Pershing, N.A.S.A. Programs, Scout and Little Joe.

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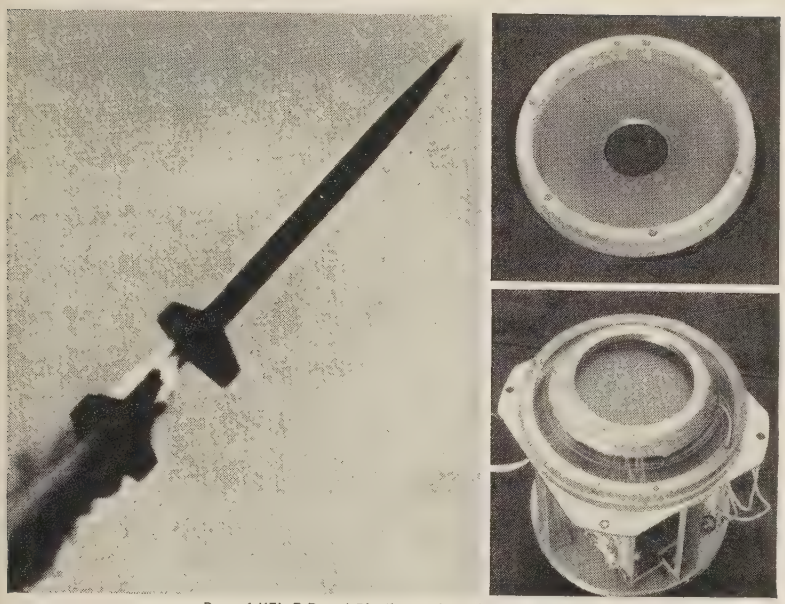
3M COMPANY CHEMICALS

THE RAW MATERIALS OF PROGRESS



Disc of KEL-F Brand Plastic provides the structural base on which various radiation analyzer components are mounted, either by screws or epoxy resin cement.

Space-exploring analyzer rides on KEL-F® BRAND PLASTIC to conquer heat, shock, electric current

Retarding potential analyzers, developed and made by Comstock and Wescott, Inc., Research and Development Engineers, Cambridge, Mass., measure extreme ultra-violet radiation in the upper atmospheres. They have flown aboard Aerobee-Hi and Nike-Asp rockets—are under development for satellite use. And the supporting base (see pictures) that helps keep these radiation analyzers on the job is made of KEL-F Brand Plastic because it provides thermal stability, toughness and high dielectric strength.

KEL-F Plastic, supplied in sheet form by American Durafilm, Newton Lower Falls, Mass., must withstand a variety of extreme temperatures at Comstock and Wescott. It is first "stress-relieved" at up to 400°F. for 24 to 48 hours, then machined to proper dimension and heat-treated at 300 to 380°F. for hardening. In assembly, various analyzer components are fastened to the base of KEL-F Plastic by screws and by epoxy resin cement cured at 200 to 220°F. The plastic remains thermally stable through these high temperatures *without* change in size or electrical properties.

On the rough ride into space, the base of KEL-F Plastic must provide a firm foundation to protect the instrument. In addition, the outstanding insulation qualities of KEL-F Plastic prevents electric current leakage—enables the analyzer to measure current as small as a millionth—millionth ampere. For more information on KEL-F Plastic, see the "profile" at right.

"KEL-F" is a Reg. T.M. of 3M Co.

PROPERTIES PROFILE

KEL-F PLASTIC BRAND

For the aerospace designer and manufacturer, KEL-F Plastic offers an unusual combination of dielectric, mechanical, thermal and chemical properties.

Electrical Properties

	Dielectric Constant	Dissipation Factor
100 cycles	2.65	.0212
10,000 cycles	2.45	.0235
100,000 cycles	2.38	.0200
100 cycles, 30° C.	2.66	.0174
100 cycles, 105° C.	2.86	.005
100 cycles, 152° C.	2.91	.002

Electrical Strength in Oil

Caliper—.01922 in.
1″ electrode.....1,250 vpm
2″ electrode..... 988 vpm

Surface resistivity $> 1.4 \times 10^{15}$ ohms run at 500 VDC

Volume resistivity $> 3.1 \times 10^{16}$ ohms run at 500 VDC

KEL-F Plastic provides zero moisture absorption —minimizes surface flash-over. Arc resistance is greater than 360 seconds.

Physical Properties

Tensile Strength	4,500 psi
Impact Strength	3.6 ft. lb./in. of notch
Compressive Strength (0.2% offset)	4,300 psi
Modulus of Elasticity	132×10^3 psi
Shear Strength	6,400 psi
Operating range	–400 to +400°F.

In addition, KEL-F Plastic is unaffected by most corrosive media—resists organic solvents, strong caustics, oxidants, missile fuels, concentrated acids, even fuming nitric.

This plastic is readily molded by standard equipment by injection, compression, extrusion or transfer methods. Parts may be machined to close tolerances—may be drilled, punched, polished, buffed or sanded as required.

For added technical information about KEL-F Plastic, write 3M Chemical Division, Dept. KAO-121, St. Paul 6, Minn.

CHEMICAL DIVISION

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3M COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

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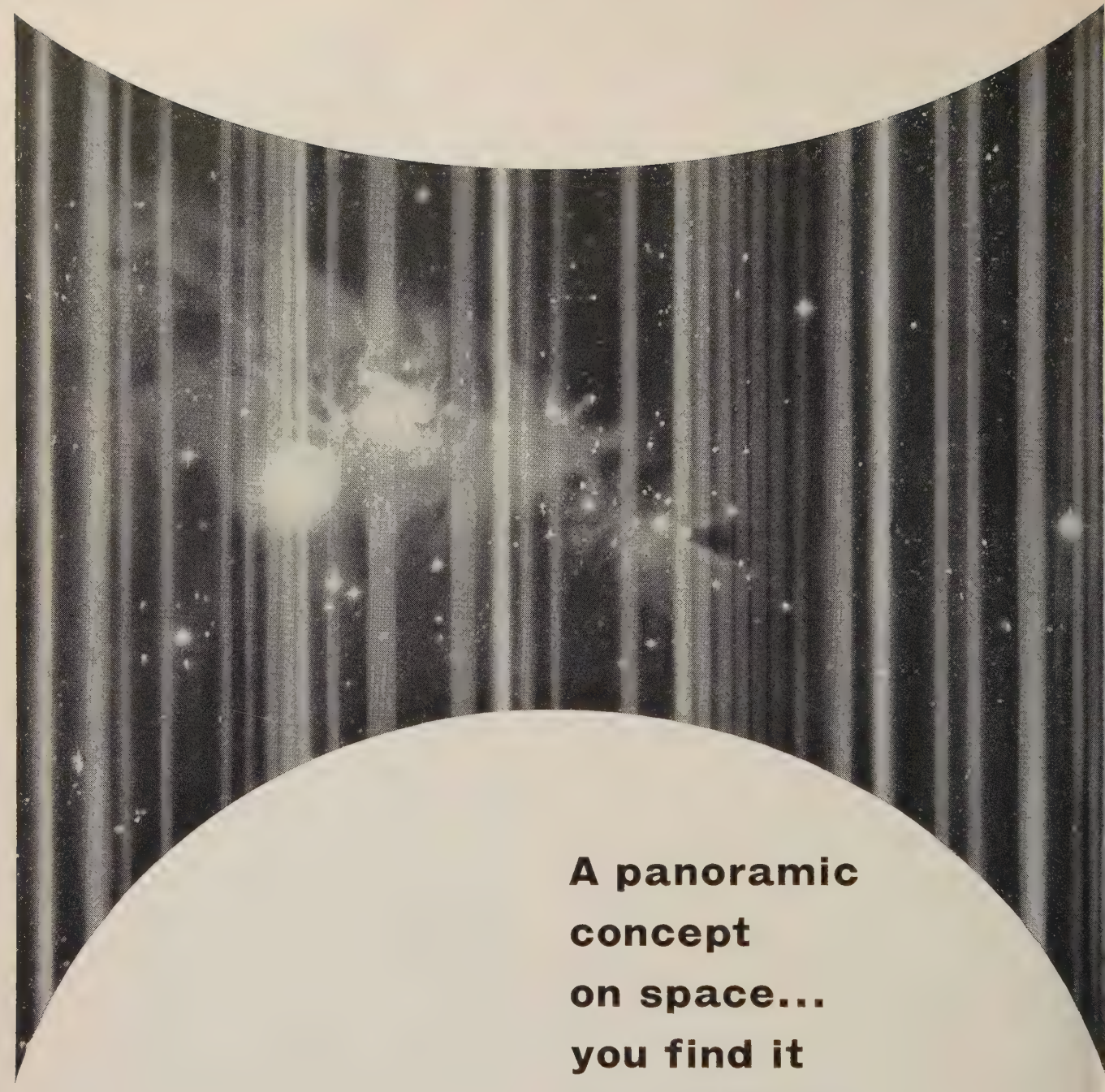

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Long experience and proven capability give Lockheed a great advantage: perspective on space. This results in programs that cover the broad spectrum of aerospace dynamics; that present the most far-reaching technological problems; that offer endless creative challenge to Scientists and Engineers; that give them new concepts to explore—new goals to reach.

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When mobility is the question, call in FMC, since 1941, a leading designer and builder of military standardized vehicles.

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ORDNANCE DIVISION

1105 Coleman Avenue, San Jose, California

PUTTING IDEAS TO WORK FOR NATIONAL DEFENSE

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SATURN LIFTS OFF!

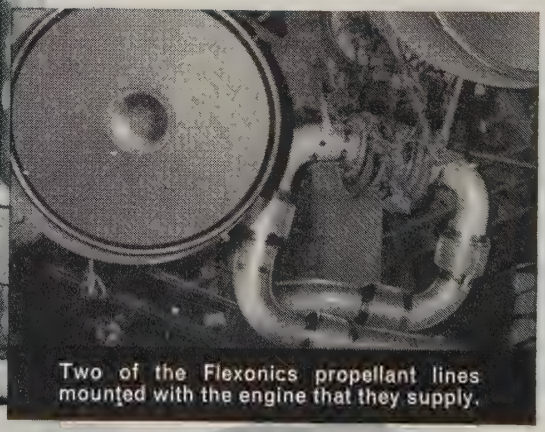
. . . with flex-metal tubing and ducting from Flexonics

The successful launching of the mighty Saturn developed by National Aeronautics and Space Administration—the United States' biggest space vehicle, producing 1,300,000 pounds of thrust—marks a giant step toward the conquest of outer space. Vital to this performance were the 16 Flexonics propellant lines supplying the cluster of eight Rocketdyne engines, plus Flexonics interconnect and pressurization lines, and high-performance metal hose.

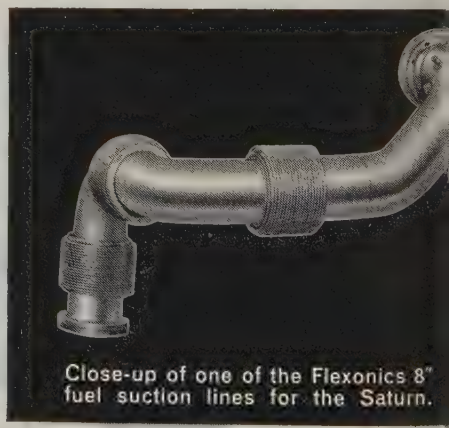
Engineers from Flexonics and George C. Marshall Space Flight Center, Huntsville, Ala., worked together in the designs of these components, just as they are now at work on future Saturn configurations. Teams of design and fabrication specialists adapted Flexonics precision-forming methods to the unique requirements of the Saturn. Exhaustive qualification tests, under simulated flight conditions, proved the soundness and reliability of design before the countdown of the first flight.

To simplify and expedite resolution of *your* next ducting problem, call on Flexonics.

Write for your copy of the big new Flexonics Engineering Guide and catalog of aerospace components.



Two of the Flexonics propellant lines mounted with the engine that they supply.



Close-up of one of the Flexonics 8" fuel suction lines for the Saturn.

Flexonics

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In CANADA
FLEXONICS CORPORATION OF CANADA, LTD.
BRAMPTON, ONTARIO

Engineer wears three hats

GIVING ONE MAN two jobs or assigning two men to one job is poor—very poor. You should keep things simple, give one man one job, and you'll get results.

Thus the management experts, with their fondness for belaboring the obvious.

But what do you do when things can't be kept simple, for the good reason that they aren't simple to start with? The management experts may not have to face this question, but the aerospace industry does.

The day of the simple aerospace project is past. Even a relatively straightforward project involves half a dozen or more different technologies that once were strictly separated. The really big projects—involving the undersea regime, say, or nuclear power—as likely as not reach beyond the capabilities of the industry and can't be handled unless other groups are brought in, and with them their ideas about how things should be done. No matter how much we'd like to keep our organization charts simple and uncluttered, there are going to be more and more overlapping responsibilities, more jobs parceled out among groups of different background, more men wearing two hats.

THAT THIS does not spell the end of aerospace progress has been proved again in recent months by Harold B. Finger, who is both chief of nuclear propulsion in NASA's Office of Launch Vehicle Programs and director of the AEC-NASA Space Nuclear Propulsion Office (SNPO). When Finger, who had spent his entire career up to then with NASA, took on the AEC-NASA job in September 1960, his chances of success weren't rated very high. There had been stiff competition for the job from an AEC official with considerable Congressional backing, NASA and AEC were not at all agreed on the purpose, timing, and safety aspects of nuclear rocket propulsion, and there was an advisory committee in the background ready to shoot down the entire nuclear rocket project at the first sign of faltering. It was also counted against Finger that as an engineer he had evidently been too busy to develop the qualities of one-upmanship allegedly so essential to survival in Washington and interagency politics.

We are happy to report—in the unlikely event that it has escaped your notice—that SNPO has been doing a bang-up job in its short existence to date, running tests, letting contracts, and perfecting plans at a great rate. Finger himself just got a nice vote of confidence: a third hat as manager of NASA's electric-propulsion program.

Moral: Engineers, with their oddball interest in getting the job done first, may be just the right people to wear more than one hat.

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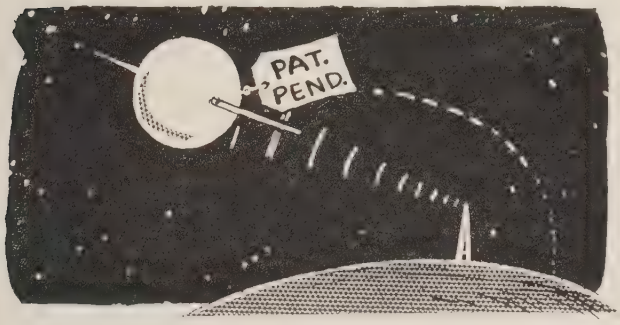
Washington Briefing

- ► NASC tackles aerospace patent problems
- ► Strike Command to have say on TFX
- ► Pentagon: Our H-bombs are big enough

Dr. Edward C. Welsh, executive secretary of the National Aeronautics and Space Council, may emerge as the key figure in the long-smoldering Capitol Hill fight over what the Government's patent policy should be on federally sponsored research.

The NASC, under Dr. Welsh, is trying to work up a uniform policy on inventions resulting from industry efforts on communications satellites. This program, when finally written, could well be the



model the Kennedy Administration will use for all patents resulting from U.S. research and development funds.

The Defense Department's attitude (with some rare exceptions) is that the U.S. should have only a royalty-free, non-exclusive license to use for its own purposes any invention which results from Pentagon R&D money. Normally, the contractor who came up with the new concept retains the right to exploit the patent commercially.

When the 1958 Space Act was written, NASA was ordered to retain full patent rights. But first Administrator T. Keith Glennan and then Administrator James Webb sought to get the Space Act amended to make NASA's patent policies pretty much coincide with those of the Pentagon.

Generally speaking, industry associations like the Aerospace and Electronics Industries Associations and the National Security Industrial Association feel that the Pentagon's existing policies are fair and would settle for some similar procedures from NASA, AEC, and FAA.

■ ■ ■

The newly formed U.S. Strike Command will be one of the most influential organizations when new manned aircraft are chosen. Pentagon officials are expected to pay particular attention to the needs of the new unit, which was specially created to meet limited war requirements by a merger of the Tactical Air Command and the Strategic Army Corps.

One of the key officers in the Command as far as plane development and procurement are concerned will be **Clifton F. Von Kann.** As a brigadier general, Von Kann has been director of Army Aviation since 1959. In his two-star post with the Strike Command, which is now being activated at McGill AFB, Fla., he will serve as Assistant Chief of Staff for Operations.

It is doubtful that either Von Kann or any other Strike Command official will be able to influence the choice of interim tactical fighters.

These, from all appearances, will be **Douglas A4Ds.** The 1963 Defense budget, to

SILICONE NEWS from Dow Corning

Beyond all specs...

Here's Why Silastic Is Used In Man's Probes Into Space!

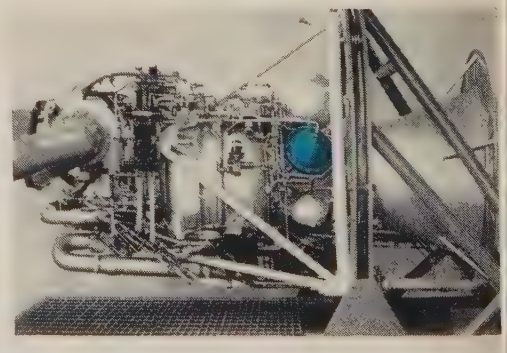
By surpassing all design specifications, the X-15 is rapidly expanding our knowledge of the performance of materials, systems and men in controlled flight to the edge of space. That's why only proven materials were selected. One of these materials is Silastic® LS, the Dow Corning fluorosilicone rubber that resists oils, fuels and solvents.

Engineers of Reaction Motors Division of Thiokol Chemical Corporation specified an accumulator diaphragm of Silastic LS for the X-15's XLR-99 engine. The accumulator provides oil at a constant pressure to the lube oil pump. Gaseous nitrogen under pressure is the source of stored energy, and is separated from 4-11V Halocarbon oil by the Silastic LS.

Here are diaphragm requirements the designers established as essential: An elastomer flexible from —80 to 200 F (Silastic LS maintains its flexibility from —80 to 500 F); compatible with the lube oil at low and elevated temperatures (Silastic LS has little swell or change in durometer readings after immersion in many hot oils, fuels and some hydraulic fluids); will not contaminate lube oil (Silastic LS has no plasticizers or additives which can contaminate by leaching).

Silastic LS... the only elastomer to meet all these requirements... helps the X-15 as it knocks on the door to outer space.

Shown below is the XLR-99 rocket engine. The lube oil accumulator is the light weight type... made possible by the diaphragm of Silastic LS... instead of the heavy, bulky piston type. Parts of Silastic can be engineered to meet your specific needs by your rubber fabricator.



For information about Silastic LS and a list of part suppliers, write Department A324, Dow Corning Corporation, Midland, Michigan.

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be submitted in January, will include enough funds to purchase between 300 and 400 of these Navy planes, which will be used by USAF to fill the Army's troop support requirements. The Pentagon is still toying with the idea of acquiring Republic F-105s, Lockheed F-104s, or Navy-McDonnel F4Hs as the interim troop support plane, instead. However, the A4D will probably win out—largely because it is much less expensive than any of the other fighters.

But regardless of which vehicle is chosen for the interim purchase, it will be followed by the **Navy VAX**, and later by the socalled **tri-service TFX**.

The VAX will be no problem. It will be procured and developed by the Navy, and will be operated by the Navy from carriers to support Marines and by USAF to support Army troops. The best bet is that it will turn out to be an aircraft with many of the characteristics of the F4H. Some 1500 will be bought.

However, the TFX program, which will eventually cost $6-7 billion, is still causing headaches—not only for the manufacturers, but also for DOD personnel who are trying to reconcile the divergent thinking of USAF and Navy.

The Navy still wants a plane that is really an air superiority fighter, with a fire control system that can lock on the target. It would weigh about 55,000 lb and be about 56 ft long, to permit easy storage aboard carriers.

USAF wants a supersonic, nuclear bomb-carrying airplane for 150-200 mile dashes, with high speed on the deck as well as top performance at high altitudes, weighing 60,000 lb and measuring about 73 ft long.

There is also still considerable doubt about when the TFX will be operational and how it will be equipped. Navy hopes for a flying model, carrying some variation of the cancelled Bendix-Grumman high performance Eagle missile, by 1968. USAF will accept an improved Sidewinder air-to-air type of missile if the plane can be ready by 1966.

Three flag-rank officers from the Tactical Air Command, the AF systems Command, and the Bureau of Naval Weapons will start evaluating proposals later this month.

Entries were due to be submitted early in December by Boeing, Douglas, Republic, North American, Lockheed, McDonnell, Convair, Grumman, and Ling-Temco-Vought, individually or in teams.

■ ■ ■

Russian resumption of nuclear tests and the Kremlin's possession of a 50-to-100 megaton hydrogen bomb have caused the Weapon System Evaluation Group to take another look at U.S. nuclear capabilities. The tentative conclusion right now is that we're pretty well set.

Although the Convair Atlas and the Martin Titan ICBMs both carry warheads in the two-megaton class and the Boeing Minuteman and Lockheed Polaris payloads are even smaller, the Pentagon's conviction remains that hydrogen weapons of this size are all that is needed to knock out any Soviet target. Weapons of 50 megatons or more can "overkill" any target, the WSEG feels.

Within the Atomic Energy Commission, the view is just about the same. One AEC official sums it up: "If the Russians wanted to knock out any U.S. city, they could do the job more effectively with several smaller H-bombs."

In the Air Force's opinion, the Soviet superbombs indicate that Russia places at least some reliance on the mixed-force concept. Manned bombers of the B-47, B-52, B-58, and B-70 class could not only carry larger H-bombs than ballistic missiles; they could also haul a mixture of several bomb sizes, dropping them for most effective elimination of targets.

AEROSPACE

FAA, NASA press forward with work on supersonic transport

FAA will use the Air Force's contracting setup to award up to $11 million in study contracts for a supersonic transport (SST) early next year. Study specs are already being drawn up at USAF's Logistics Command for a Mach 3 aircraft that will be 200 ft long and have a 100-ft wing span.

To expedite SST development work, FAA Administrator Najeeb Halaby picked USAF Col. Lucian S. Rochte, Jr., to run FAA's Supersonic Transport Program Management Office. Rochte previously was chief of the aircraft branch in FAA's Office of Plans. As consultants on the SST, Halaby named Al White, NAA's B-70 test pilot, and Gen. Orval R. Cook, who will head a special SST advisory group from industry. Charing recently retired as president of AIA.

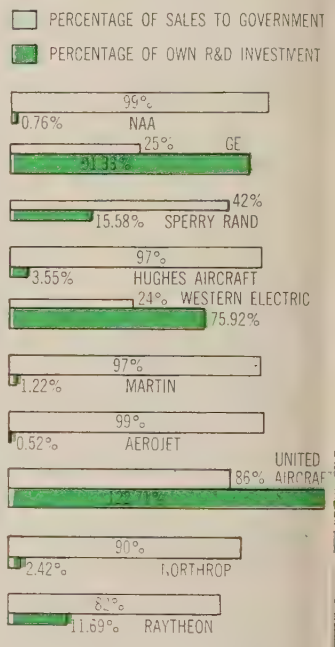
Sonic-Boom Tests FAA's $11 million will be spent on research on materials, propulsion, stability and control, variable-wing sweep, improved cruise lift-drag ratios, and other problems of Mach 3 operation. The companies picked by FAA for this job will be given the results of special sonic-boom tests now being made near Edwards AFB, Calif., with B-58s, F-104s, and F-106s.

Meanwhile NASA is urging that work be started soon on SST simulators, which it says should be ready by '65. NASA claims it is putting 15-20 per cent of its total research effort into SST development.

Swing-Tail Cargo Jet for USAF? Though the Air Force now has the authorization to buy Boeing C-135 cargo jetliners for MATS and has a development program going on the Lockheed C-141 cargo turbofan, it still hopes to acquire 150-200 cargo jets with swingaway tails for interim use until the C-141 is available. After deciding that Canadair's CL-44 turboprop, which features a swing tail in its advanced versions, has considerable merit, USAF asked Boeing, Douglas, and Convair to make proposals on the cost of transforming the 707, DC-8, and 880 and 990 into swing-tail cargo planes. Apparently, the cost would be considerable—USAF could get the necessary money only by persuading the House and Senate Armed Services and Appropriations Committees to let it re-program money voted for other aircraft for fiscal '62 or by persuading Defense Secretary Robert McNamara and the President to let it use the extra money voted for bombers by Congress.

Fifteen-Billion Program Our overall ballistic-missile program is costing us about $15 billion, according to Maj. Gen. Thomas P. Gerrity, commander of AFSC's Ballistic Systems Division. Of this sum, he estimates, $1.5 billion is being spent on site construction.

Company R&D How much money of his own a top defense contractor invests in R&D depends on how much he sells to the civilian market, a survey by the Senate's Subcommittee on Patents seems to indicate. Figures for the 10 leading defense contractors in the '49-'59 period show that the ratio of R&D money they got from the government to the funds they put up themselves range from 191.67:1 (Aerojet-General) to 28.17:1 (Hughes Aircraft) for the four firms that made 90 per cent or more of their sales to Uncle Sam. For companies deeply engaged in commercial business (accounting for about 75 per cent of their sales), the ratios were much smaller—13.17:1 for Western Electric and only 1.09:1 for GE.



An exception to the pattern was United Aircraft whose own investment in its R&D slightly exceeded the government's, even though 86 per cent of its sales were made to the government. The middle ground is occupied by Sperry Rand, which made 42 per cent of its sales to the government and got 6.42 times as much money from Washington for its R&D as it put up itself.

Cheaper Big Liquids? Rocketdyne and Aerojet-General are studying liquid rockets delivering 2,000,000-24,000,000 lb thrust under NASA contracts worth $185,000 each. NASA hopes the two companies can come up with unconventional designs that will cost less and be more reliable than existing rockets.

The new rockets are to use lox and either a hydrocarbon fuel or liquid hydrogen. If the studies look promising, Aerojet and Rocketdyne are supposed to evolve design criteria.

Dyna-Soar Funding Like the B-52 and the B-70, Boeing's manned Dyna-Soar space glider suffered a setback when President John F. Kennedy decided not to use the extra money appropriated by Congress for the three craft (which came to $87.7 million in the case of the Dyna-Soar). The $70 million USAF did get for Dyna-Soar is being spent quickly, though. The Air Force has already issued $36.5 million fiscal '62 money in contract extensions—$30 million to Boeing, $3.5 million to RCA for R&D on communications and tracking, $3 million to Minneapolis-Honeywell for the primary guidance system.

According to present plans, a Titan II booster will be used for the Dyna-Soar. However, USAF is studying "every possible means"—including the Saturn 1,300,000-lb-thrust booster—to speed up the program.

INTELLIGENCE

Advisors' Tasks The non-profit Logistics Management Institute, the Pentagon's latest advisory group, has been handed its first batch of assignments. All have to do with improved defense procurement techniques.

LMI will begin by looking over DOD's purchase to see if they contain unnecessary requirements that might result in duplication and other waste. It has also been directed to develop systems that "will rapidly determine what is required to support changes in operational plans and to appraise our material readiness to support these plans." Further LMI study areas include how-to-buy techniques, with an eye toward bringing down inventory levels as well as administrative procurement costs.

Tri-Nation Spacecraft Great Britain's Minister of Aviation, Peter Thorneycroft, announced plans for a joint Western European satellite program at a meeting of a nine-nation group in London. The booster of the projected three-stage launch vehicle is the English Blue Streak which is based on the Atlas and is to be flown from the Woomera test range in '63. An attempt at putting a satellite in orbit is slated for two years later. (See *"Blue Streak Now Slated for Satellite Launches," p. 69.*)

The second stage is to be a French Veronique, and West Germany will provide the third stage, which has yet to be developed. Sweden, not a member of the team but present as an observer at the London meeting, has a rocket it considers suitable for use in the third state—the Svenska Flygmotor VR-3.

France meanwhile is continuing to develop complete spacecraft. It has projected a three-stage satellite launcher which would consist of an Ameraude first stage and a Topaze second stage (both liquid) and a solid-propellant Diamant. This combination is to put up to 175 lb into orbit. The recently created Centre National d'Etudes Spatiales will try to launch the first French satellite by '64.

Short-Trajectory Saturn Flight Boosts U. S. Space Program

With the successful Saturn launch on October 27, the U.S. space program took a giant step forward. The total weight of the vehicle on the pad was over 920,000 lbs. Almost 200,000 lb of water was used to simulate the weight of upper (S-IV and S-V) stages, which were inert for this test. The eight Rocketdyne H-1 first-stage engines were ignited in pairs with 100-millisecond delays. When all eight were running, the vehicle was held by holdown arms for almost four seconds before launch took place. The total take off thrust, NASA estimates, was about 1.3 million pounds. Vehicle height for this first of 10 planned R&D launches was about 162 ft.

The flight, over a short trajectory of about 225 miles, lasted roughly eight minutes and reached a peak altitude of about 90 miles. Tilt began about 10 seconds after lift-off and continued for about 90 seconds, after which the vehicle was inclined about 43 deg from the launch vertical. The four inner engines were cut off at 109 seconds, the four outer ones at 115 seconds—two seconds earlier than planned. The staggered shutdown was designed to prevent excessive oscillations.

610 Telemetry Channels Some 610 telemetry channels were used in the test, about 510 of them for flight measurements (fuel levels and flow rates, engine bearing temperatures, velocity measurements, etc.). The remaining channels carried countdown and flight data for immediate observation.

The H-1 engines in the Saturn used a simplified start sequence involving a solid-propellant gas generator. The turbogroup on each thrust chamber was moved below the gimbal block so the flexible feed lines to the engine had to carry only low-pressure propellant.

Mercury Off for '61 Postponement for at least a week of the projected orbital chimpanzee flight, the final check before orbiting a man in a Mercury capsule, killed the chances of achieving that goal this year. The delay was caused by leakage in the hydrogen peroxide supply of the Mercury capsule's attitude control system.

The chimp flight will be a three-orbit trip at an altitude between 100 and 150 miles. The chimp is to be carried in a special container inside the Mercury capsule, connected to the capsule's life-support system in the same way as an astronaut's space suit. The flight would evaluate the operation of the support system and also check the monkey's reactions to the stresses of the trip.

Discoverer XXXIV The twenty-second successful orbit was achieved in the Discoverer program out of 34 tries. The Thor-Agena B launcher got off in what the Air Force called "a real clean shot," but all attempts to recover the Discoverer XXXIV instrument capsule had to be called off because of a malfunction in the satellite after it went into orbit. The Discoverer XXXIII had been sent up from Vandenburg AFB, Calif., a little more than a week earlier but failed to go into orbit when the Agena's motor shut off too soon after separation.

Too Cold for Needles? Project West Ford's package of minute copper-dipoles was carried into orbit with the successful launching of Midas IV, but the Air Force couldn't find the belt of copper needles that was to form as the material in which the needles were imbedded evaporated in space. Project scientists suggested that it was colder in space than they had expected and evaporation has been slowed down.

More Monkey Business Less lucky than the Mercury chimp was a squirrel monkey riding in an Atlas booster that veered off course shortly after lift-off and was destroyed by command from the Cape Canaveral, Fla., control center. The tiny monkey in the nose cone was to be photographed during the flight to record its reactions to a twenty-minute period of weightlessness. The Atlas also carried equipment to test the effect of

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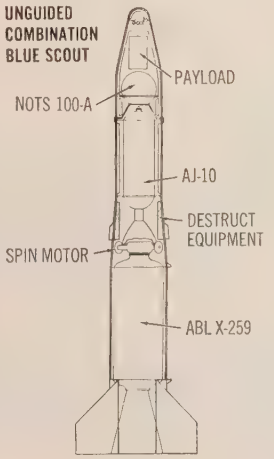
radiation in space on biological samples, including fruit flies, bread mold, insect eggs, and viruses.

Other living samples are scheduled to be launched through the Van Allen belts, and a mass of debris from a decayed comet, from Point Arguello, Calif., as part of the Bios I (*b*iological *i*nvestigations *o*f *s*pace) program. The effects of weightlessness on cell division and egg fertilization are also to be studied in this experiment. The launch vehicle will be a four-stage, solid-propellant Scout.

Minor Changes Adapt Blue Scout to Air-Launch from X-15

Aeronutronics and NAA have worked out a design for air-launching the upper two stages of the Blue Scout from the X-15. They claim that the air-launched craft could perform missions difficult or impossible to tackle from ground sites and that the cost per mission would be much lower. For an unguided probe mission, they state, 50 per cent of the cost could be saved, or about $125,000 per vehicle. With the X-15 Blue-Scout combination, it is further claimed, two launches per month could easily be made, as against one per month from the ground as at present.



An example of a mission that requires air-launching, engineers told SPACE/AERONAUTICS, is the orbiting of an unguided spin-stabilized payload. This mission could not be attempted from the ground, they stated, because of the high heating resulting from the low launch angle. Missions requiring rapid pitchover also pose extreme guidance and control problems if they are ground-launched, the engineers noted.

Few Changes Only minimal changes to both would be needed, Aeronutronics and NAA claimed. On the Blue Scout, the second-stage fins would have to be resized (their tips would have to be clipped off), the spin-stabilizing rockets would have to be moved to one of the two upper stages, and a larger heat shield would be needed (a matter of taking the heat shield from a Blue Scout Junior and lengthening the conical section by 10 in.) On the X-15, the engine would have to be realigned to the new CG and launch rails would have to be installed. The combination system could place 50 lb into a 800-nm orbit,100 lb into a 400-nm orbit, and 125 lb into a 300-nm orbit.

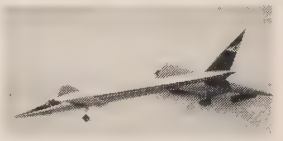
Looking beyond the X-15, it's been estimated that the B-52 could launch a vehicle roughly twice the size of the X-15 and weighing about 70,000 lb. Such a craft would approach the characteristics of the next generation of spacecraft.

Launched Twice The first and second underwater launchings of a liquid-propellant vehicle were made with the same modified Aerojet Aerobee-100—the first time also that a recovered vehicle has been fired again. The 17-ft, 2600-lb-thrust Seebee lifted out of the water a few miles offshore from Pt. Mugu, Calif.

The sea-launching tests were part of a program financed by Aerojet-General and tied in with the Navy's Project Hydra. Its aim is to prove that very large boosters can be launched from the water. Aerojet believes that the giant liquid-propellant vehicles for lunar and planetary trips should be built in a dry-dock, towed to sea, serviced, loaded and ballasted to a vertical position, launched, and then recovered for re-use—an economical, safe, and flexible operation, says the company. Re-use of the giant boosters could bring the cost of orbiting a pound of payload down from $1000 to a mere two dollars. A total of more than forty successful launches have been made so far by the Naval Missile Center as part of the Hydra program.

Polaris Firings First underwater launching of the 1725-mile-range Polaris A-2 was made from the Ethan Allen, newest and largest of the subs carrying the Lockheed missiles. The two-stage, solid-propellant missile covered about 1000 miles. Its design range is 1725 miles—350 miles more than the operational A-1's. The Ethan Allen had fired an A-1 missile in its first test a week previously.

Lufthansa's SST A clue to what this country's supersonic transport may look like was provided by Lufthansa, which unveiled a scale model based on its discussions with U.S. aircraft builders. The German airline's SST seats 140, cruises at 4225 miles at altitudes of 12-14 miles, and uses four 39,700-lb-thrust bypass turbojets. It is 203 ft long, 48 ft high, and has a 98-ft wing span. Takeoff weight is 396,830 lb; payload, 32,520 lb; maximum landing weight, 242,510 lb.



X-15 Hits 4093 mph The speed phase of the X-15 test program was completed with a 4093-mph flight, with AF Maj. Robert M. White at the controls. Temperature at points on the skin rose to 1100 deg F. During the glide back to Edwards AFB, Calif., the outer right panel of the windshield shattered, probably because of thermal stresses on the windshield frame. The inner panels and the rest of the windshield remained undamaged.

The rocket motor was operated at full thrust until burnout after 86 seconds. The speed mark was hit in level flight at 95,800 ft just as the fuel was exhausted. White then coasted to 101,000 ft, checking the high-speed handling characteristics under both manual and automatic control.

The next step in the test program will be an attempt

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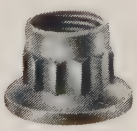
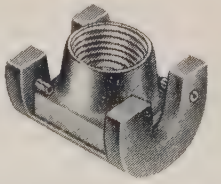
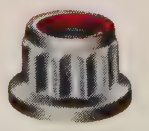


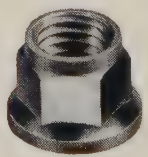
LH3393T, (220,000 psi)
LHEB220T, (220,000 psi)



LH2577T, (180,000 psi)
LH3220T, (220,000 psi)



EBT,(180,000 psi)



LH3489T, (180,000 psi)

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to reach the maximum design altitude of 250,000 ft. White has already hit 217,000, and the plane is expected to be able to go up to something like 100 miles. Further plans for the next two years call for use of the X-15 in re-entry research.

Assault Transport Copter Sikorsky is working on a new copter to meet requirements for a heavy assault transport for both land and carrier operation. Already in the hardware stage, it is based on the main and tail rotors and transmission systems of the S-64 Skycrane. Among its features are a 4-9-ton capacity, a hydraulically operated rear-loading ramp, a retractable tricycle landing gear, automatic blade and tail folding systems, and a high-speed, heavy-duty cargo handling system, with an automatic external cargo pick-up probe requiring no ground personnel. Powerplants will be proven turboshaft engines, already in production. The design generally is based on use of proven components. The rotor system, for instance, has already been operated for many hours on a special test stand in connection with the S-64 project.

BAC Scores with 111 British Aircraft's 50-70-passenger BAC 111 was ordered by Braniff. It's the first British pure jet to be sold to a U.S. airline.

The 111 is powered by tail-mounted Rolls Royce Spey turbofans rated at 10,400 thrust each. In the standard configuration, it will carry seven tons over 700 miles at a cruising speed of 500 mph. Its range is slightly shortened by operation at a maximum speed of Mach 0.78 and can be increased to 1100 miles by the addition of optional tankage. Take-off with full payloads at sea level and 59 deg F requires only 5000 ft for a block of 500 miles.

Cold-Weather Parameters Aircraft operation in extreme cold weather may become more important in the future because of the strategic value of the Arctic regions, it was stated at a joint meeting of the Canadian Aeronautical Institute and IAS at Ottawa. T. G. Dunkin, of Canadair, noted that the load bearing capacity of ice, or its resistance to bending under load, involves parameters like thickness, pressure exerted by the water when deflection of the ice takes place, Poisson's Ratio, Young's elastic modulus, and shape and direction of the applied load.

One result of the movement of aircraft or other heavy loads on ice of marginal thickness, Dunkin said, is the creation of resonance waves. These are particularly dangerous when planes taxi at speeds that correspond to the propagation speeds of ice waves. The Russians, Dunkin said, have already set up rules for the speed and spacing of vehicles on ice to avoid this effect.

New Fatigue Theory Prediction of fatigue failure with considerable accuracy was claimed for a new, comprehensive theory developed by Dr. S. R. Valluri, of Cal Tech. Though he admits his theory has certain limitations, Valluri believes that it "is amenable to a successful treatment of the failure problem of complicated structures. The analytical expressions that have been derived have been confirmed to a considerable extent by tests performed in industrial and government laboratories across the country." In one instance, it's claimed, the errors in a fairly complicated type of loading averaged less than five per cent.

One of the important postulates of Valluri's theory is that submicroscopic cracks preferentially form ahead of a leading crack. The merging of the submicroscopic cracks with the larger crack ultimately causes the failure. It is an intermittent process, according to Valluri, involving an active growth period followed by a dormant period. The result of such a growth pattern, he states, shows up in the form of rings, much like the growth rings in a tree. By establishing the length up to which the crack can grow, given a set of loading conditions, his mathematical expressions make it possible to determine the life of the structural component, Valluri states.

To apply Valluri's theory, two factors must be known:

- the nature of the stresses to which the structure is subjected and their extent
- the basic behavior of the metal during fatiguing (on which, Valluri points out, considerable data are now available as a result of work in solid-state physics and physical metallurgy).

Lighter Magnesium Alloy A new developmental magnesium alloy containing 11 per cent or more of lithium is being studied at Battelle Memorial. It is said to weigh about 25 per cent less than magnesium, 50 per cent less than aluminum, and 75 per cent less than stainless steel. Even more important is that the alloy has a more ductile crystal structure than does magnesium. It is also said to have excellent resistance to penetration by high-velocity particles.

Beryllium Data Recent beryllium studies were discussed at a British Institute of Metals symposium in London by Lockheed researchers. M. E. Tatum noted that tensile strengths of 40,000 psi and yield stresses of 30,000 psi are shown by hot-pressed block made from −200 mesh powder with a 1½-2 per cent oxide content. To improve the yield in machining parts made from block, Lockheed has turned to "chevron cutting" in which a stack of several parts is machined from a single block. The largest part made to date in this way was a thin-walled, truncated cone about 72 in. in diameter and 27 in. high.

Studies of beryllium near the melting point, W. G. Bradshaw and E. S. Wright reported, show that cor-

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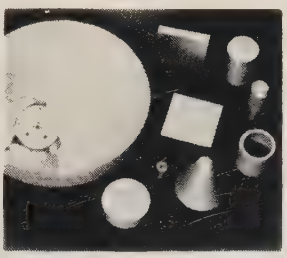
rosion at high temperatures and near-atmospheric pressure is different from the corrosion in pure oxygen or nitrogen at lower temperatures. In air, the reaction is characterized by an induction period followed by a fairly rapid, linear increase in corrosion. The Lockhead engineer noted that the corrosion product formed in air seems to be porous rather than protective, as is the case in pure nitrogen or oxygen. The induction period seems to be due to the presence of a thin, protective film which is broken up by high temperature corrosion in air. For short-term applications, however, the reaction doesn't become extreme until temperatures over 1200 deg C are reached, it was stated. (See also, *Beryllium for Aerospace Structures," p. 64.*)

Ae-SS Bonds A flux-free method for joining aluminum to stainless steel was reported by AEC. In work at Hanford Atomic Products, it has resulted in gas-tight, durable bonds, it's stated.

The steel is cleaned with an abrasive, washed in trichlorethylene, coated with a solution of equal parts of water and concentrated hydrochloric acid, preheated to 450 deg F, and tinned with 50Pb-50Zn solder. It is then rinsed with hot water to remove any acid that may not have been removed by the preheating. The aluminum is cleaned with abrasive and washed in trichlorethylene. After preheating to about 650 deg F, it's tinned with aluminum (0.01Al-0.01Cu-1Fe-1Pb-0.1Si-97.88Zn) solder.

The two surfaces are then placed in contact and heated to 500-600 deg F with an oxy-acetylene flame. The materials readily join to form a gas-tight joint, Hanford states.

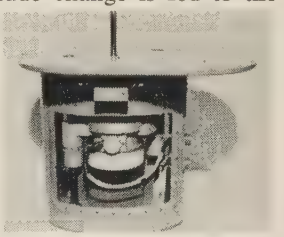
Beryllides Beryllium-based intermetallic compounds will raise the maximum operational temperature for missile and satellite structural materials by about 50 per cent, according to Brush Beryllium. The new materials, made from beryllium chemically combined with a refractory metal, are very strong and highly resistant to oxidation even at 3000 deg F. They weigh about the same as aluminum. This combination of properties makes them highly suitable for hypersonic and re-entry structures, it is claimed. They also have high specific heat and good thermal conductivity and so could serve as heat-sink materials.



Seven intermetallic beryllide compounds have proved most promising in the course of its five-year program, Brush Beryllium states. Two of them, $TaBe_{12}$ and Ta_2Be_{17}, are already commercially available and the other five (two using zirconium and three using columbium), are expected to become available shortly.

The beryllides can be fabricated by vacuum-hot-pressing, cold-pressing and sintering, investment and slip-casting, isostatic pressing and flame-spraying. Parts like cones, rods, tubing, plates, crucibles, blocks and bars so far have been made only in small sizes, but scale-up studies show excellent promise.

Saturn Transducer Four retractable angle-of-attack probes sensed the attitude of the Saturn booster during the early stages of its successful first flight. The transducer probe, which sticks out about six inches from the vehicle's skin, has a pair of narrow, longitudinal slots spaced 90 deg apart. The angle of attack is determined by measuring the air pressure differential between the slots. Each slot is connected by an interior passageway to a plenum in its base. Unbalanced pressure from the slots acting on a movable vane in the plenum makes it rotate. A mechanical linkage from the vane rotates the probe to equalize the pressure in the slots. The amount of attitude change is fed to the flight control computer.



The probe was developed by U.S. Science of Los Angeles. A delicate mechanism and easily damaged in transit or by weather, it remains retracted within the vehicle until just before launch. Thirty seconds before launch, small DC motors extend the probe and lock it into precise alignment. Electric heaters prevent icing of the slots and passageways during pre-launch and flight.

Nuclear Engine Tests The Kiwi reactor test series for the Rover nuclear space propulsion program was delayed when the portable metal shed used to protect the Kiwi B-1A was wrecked by a hydrogen explosion. The reactor was scheduled to undergo a full power test on the day the accident occurred. The reactor itself was not involved in the explosion and was not damaged, according to the Los Alamos Scientific Lab, which built it. The test was the last one scheduled for the B-1A program.

Tory II-A-1 prototype reactor for the Pluto nuclear ramjet development program completed its tests. Apparently they were successful (neither NASA nor AEC released any details). Testing of the more advanced Tory II-C reactor is next on the schedule.

Thermoelectrics A germanium-silicon thermoelectric material prepared at RCA's Princeton Laboratories yields powers of 10 kw/hr/sq ft at 1800 deg F.

Even at room temperature it produces some current flow. Heat conversion efficiencies approaching the gasoline engine's best of 20 per cent are predicted for the material after further development. In addition to its high efficiency, the alloy is the first of its kind that is stable under a high vacuum, making it a prime contender as a space power source.

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MEN BEHIND THE PROJECTS

Marmo

Studies motion of high-altitude debris

Debris motion of high altitude nuclear explosions is being studied by Geophysics Corp. of America, Bedford, Mass., under contract to the Defense Atomic Support Agency of the Defense Department. The amount of the contract is $92,330.

The debris motion studies are being made by Dr. Fred Marmo and Jerome Pressman. Dr. Marmo initiated upper atmosphere chemical seeding programs while serving with the USAF Geophysics Research Directorate. He now is GCA's principal scientist conducting upper atmosphere modification studies. As director of the company's Space Sciences Lab, he also heads GCA's lab studies of planetary atmospheres. Pressman is his chief lieutenant on these programs.

The debris motion studies draw heavily on the upper atmosphere tracer gas work by Dr. Edward R. Manring of GCA. The program is closely related to extensive studies of upper atmosphere wind motions which GCA conducts under contract to NASA.

King

Can we predict and measure high-altitude IR radiation?

Radiation effects of high altitude nuclear blasts are also being studied Geophysics Corp. of America, under contract to the USAF's Cambridge Research Labs. This work is being done by Dr. Jean King and Dr. Milton Klein, both of whom have considerable experience in radiation effects studies. Dr. King, GCA's plasma physics department manager, came to the company from General Electric's Space Sciences Laboratory (MSVD) where he was manager of physics operation in 1957. He also served with the Geophysics Research Directorate at Cambridge Research Center, Bedford, Mass. Dr. Klein, who only recently joined GCA, also came from GE's MSVD. He is a plasma physicist.

The two scientists are studying experimental techniques for predicting and measuring the extent of infrared radiation caused by high altitude explosions. Under the contract, GCA will be responsible for reviewing the physics involved in chemiluminescent reactions, etc.

Cole—"Large sample sizes to evaluate transistor reliability and failure rate are wholly unnecessary"

A way to evaluate long range transistor reliability and failure rate with much more accuracy and economy than before is being used by Philco's Lansdale Div., Philadelphia, Pa. A life test control plan permits small sample sizes to be used without the user's losing statistical confidence.

Says William P. Cole, director of reliability and quality control: "The common method of using very large sample sizes to figure reliability of each transistor lot not only is expensive for the customer, it's wholly unnecessary in many cases."

Moreover, he adds, "though such testing may tell something about the individual lot sample, nothing is revealed about preceding or subsequent lots."

By automating production lines and mechanizing in-process control, Cole says, "Philco has been able to get the product uniformity which makes sequential life test sampling possible. "Accumulated life test results are plotted in a way that shows the degree of product uniformity as well as potential reliability level. This permits the determination of the qualification level.

For each reading period, the failures are plotted for each lot. Control limits based on probability statistics are established for each reading period. If the sample exceeds the control limit, then the product may not be shipped until the life test period is finished. At that time the sample must be within the control acceptance limit as a criterion for release to the user.

Archibald

Thousands of hours more for gyro bearing life

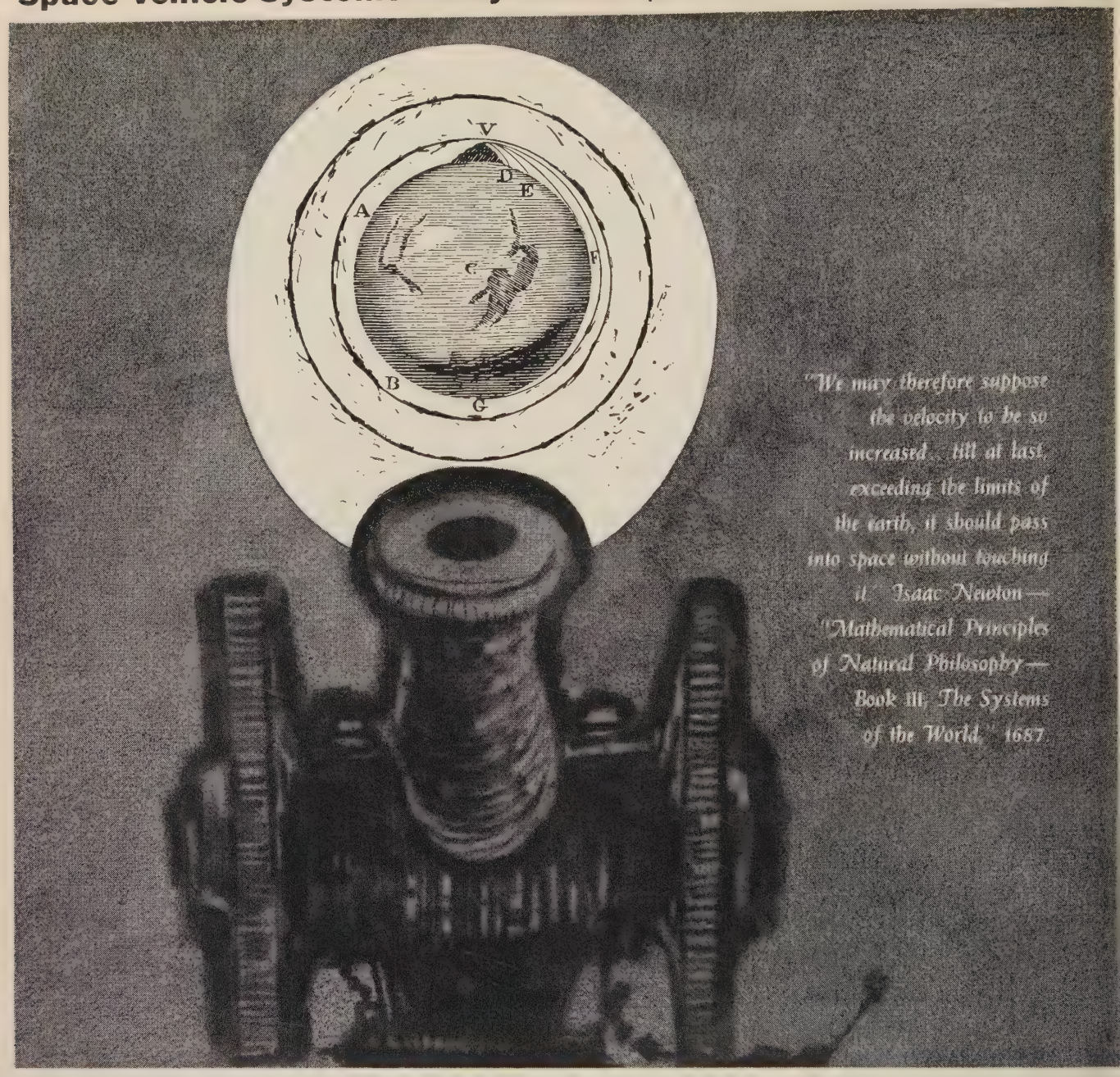
Two AC Spark Plug scientists have ferreted out a fifth columnist in our missile program. The scientific cloak and dagger work took several years to study, and the villain proved to be oxygen. By stopping the effects of oxidation in gyroscopic instruments used in inertial guidance systems for ballistic missiles, the researchers will save substantial amounts of time, labor, materials, and money.

The two men, Frank Archibald and Thomas Elbert, of AC Spark Plug Div., General Motors Corp., Milwaukee, Wisconsin, found early in their work that the presence of even the tiniest amounts of oxygen ing bearing lubricants could knock out a precision made gyroscope.

According to Canadian-born Archibald, "Finding the problem and isolating it was one thing; solving it was quite another." To his knowledge there is no completely oxygen resistant organic lube on the market.

Research for the past twenty years or so was all pointed toward the bearing itself, the two scientists say. While there were serious at-

Space Vehicle Systems Analysts for **S**pace **T**echnology **L**eadership



"We may therefore suppose the velocity to be so increased... till at last, exceeding the limits of the earth, it should pass into space without touching it." Isaac Newton — *"Mathematical Principles of Natural Philosophy — Book III, The Systems of the World,"* 1687

REPRINTS OF THE DRAWINGS CREATED FOR THIS SERIES, SUITABLE FOR FRAMING, ARE AVAILABLE ON REQUEST.

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tempts to analyze the lubricants, the very low concentrations of oxygen causing lube degradation hadn't been considered. Weighing showed that deposits of about 0.045 milligrams were enough to cause failure. The fastest and most economical way to get rid of the oxygen was literally to burn it out, the scientists found. They have developed tools and methods to do this. As a result, bearing life has been upped from several hundred to many thousands of hours, and gyro life has been increased at least three to four times. The new breakthrough is expected to make a big difference in system reliability.

Westwood

Fatty acids on surface affect strength of materials

Surface coatings affect the behavior of materials, a Russian Academician found back in 1928. This phenomenon, known as the Rebinder effect, after its discoverer, P. A. Rebinder, has been studied extensively by Russian scientists—but largely neglected here.

In a study project to be carried out under a $34,833 contract at The Martin Company, Baltimore, Md., the U.S. Army Ordnance District, Philadelphia, plans to correct this error of omission. Principal scientist on the project is British-born Dr. A. R. C. Westwood of Martin's Research Institute of Advanced Study. His research concerns the decrease in strength that sometimes accompanies the presence of fatty acids at the surface of materials. The strength of materials depends on atomic dislocations, Dr. Westwood says. He is centering his studies on ionic crystals, rather than metals, to avoid any confusing observations caused by oxide film present in most metals.

Dr. Westwood joined the RIAS staff in Nov. 1958. He had served as a technical officer in the Metals Div. of Imperial Chemical Industries in the U.K., producing the first titanium castings in Europe. He received his Ph.D at the University of Birmingham.

Sparrell

Builds super-hot measuring device

The job of building a 3000 deg F thermal conductivity measuring instrument has been handed to Dynatech Corp., Cambridge, Mass., by USAF Materials Central Lab, Aeronautical Systems Div., AFSC. Project manager is James K. Sparrell.

The instrument will be used for measuring the thermal conductivity of super alloys, honeycomb structures, cermets and ceramics for ultra high speed aircraft and spacecraft. There will be many industrial applications also, the company says. Delivery will be made this month.

A major technical problem, says Sparrell, was building a heater assembly that would operate with a reasonable life expectancy at 3000 deg F in air, inert atmosphere and a vacuum of 10^{-5} mm Hg. Another problem was selecting construction materials that could be used at 3000 deg F in those environments.

Sparrell got his BS in mechanical engineering at Norwich University and MS at M.I.T. Before joining Dynatech, he was an engineer at Connecticut Aircraft Nuclear Engine Laboratory (CANEL) a division of United Aircraft Corp., a teacher of engineering subjects at MIT, and a constultant to industry. While at CANEL, Sparrell furthered his work in the thermal area as an engineer in the analytical reactor design group. His activities included work on electric-thermal analogs, reactor temperature distribution, reactor fluid flow, and inpile loop design. He also developed a digital computer program for conducting reactor core parametric studies.

Dynatech is actively recruiting engineering personnel.

Bender

"Satellite rendezvous is an integral part of most big space efforts"

"Solutions to satellite rendezvous problems are an integral part of most major space efforts," say Dr. David Bender and Paul Des Jardins, two research scientists with the Space & Information Systems Div., North American Aviation, Inc., Downey, Calif. Both are working on a NASA contract dealing with mathematical techniques for satellite rendezvous.

They point out that a better understanding of the rendezvous process will lead to solutions for the performance of such space tasks as satellite or spacecraft maintenance, refueling in orbit, resupply of spacecraft or space station, and the maintenance of a "stationary" communications satellite.

The NASA study they are working on is aimed at deriving basic rather than applied results. However, the techniques and "tools"—computer programs—are directly usable for the study of particular orbital transfer problems, they say.

Dr. Bender has served NAA both as a consultant and an employe for six years. He first worked in the guidance analysis section at Autonetics. He has been at SISD since 1959, working on satellite rendezvous and satellite observing and prediction techniques. A graduate of Cal-Tech with BS, MS and Ph.D. in physics, he has also been head of the physics department of Whittier College, Calif., since 1946.

Paul Des Jardins has been with NAA for eight years, starting in data analysis work in flight test on the Navaho missile program. He has a BS in aeronautical engineering from St. Louis University.

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Dec. 4-5 Conference on Beryllium Metallurgy, New York University College of Engineering, New York, N. Y.

Dec. 4-6 Specialists' Meeting on Aerospace Support and Operations (classified), IAS, Orlando, Fla.

Dec. 5 2nd Annual Seminar on Reliability in Space Vehicles, IRE, Rodger Young Auditorium, Los Angeles, Calif.

Dec. 12-14 1961 Eastern Joint Computer Conference, Sheraton-Park Hotel, Washington, D. C.

Dec. 18 25th Wright Brothers Lecture, Smithsonian Institution, Washington, D. C.

Jan. 9-11 Eighth National Symposium on Reliability and Quality Control, Statler Hilton Hotel, Washington, D. C.

Jan. 22-24 30th Annual Meeting, IAS, Hotel Astor, New York, N. Y.

Jan. 23-26 Solid Propellant Rocket Conference, ARS, Baylor University, Waco, Texas.

Jan. 24-26 Second Symposium on Thermophysical Properties, Princeton, N. J. Heat Transfer Div., ASME.

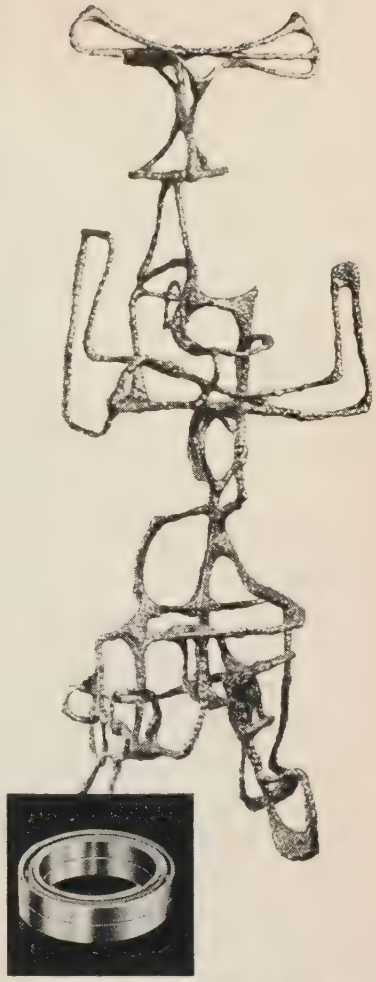
Feb. 6-7 Symposium on Redundancy Techniques for Computing Systems, Dept. of the Int. Auditorium, Washington, D. C. Information Systems Branch, Office of Naval Research.

Feb. 7-9 Third Winter Convention on Military Electronics, IRE, Ambassador Hotel, Los Angeles, Calif.

Feb. 14-16 International Solid-State Circuits Conference, IRE, Sheraton Hotel and University of Pennsylvania, Philadelphia, Pa.

Feb. 19-21 Tracking and Command of Aerospace Vehicles, IAS, San Francisco, Calif.

Feb. 27-Mar. 1 Symposium on the Application of Switching Theory in Space Technology, Palo Alto, Calif. Lockheed Aircraft Corp., Air Force Office of Scientific Research.



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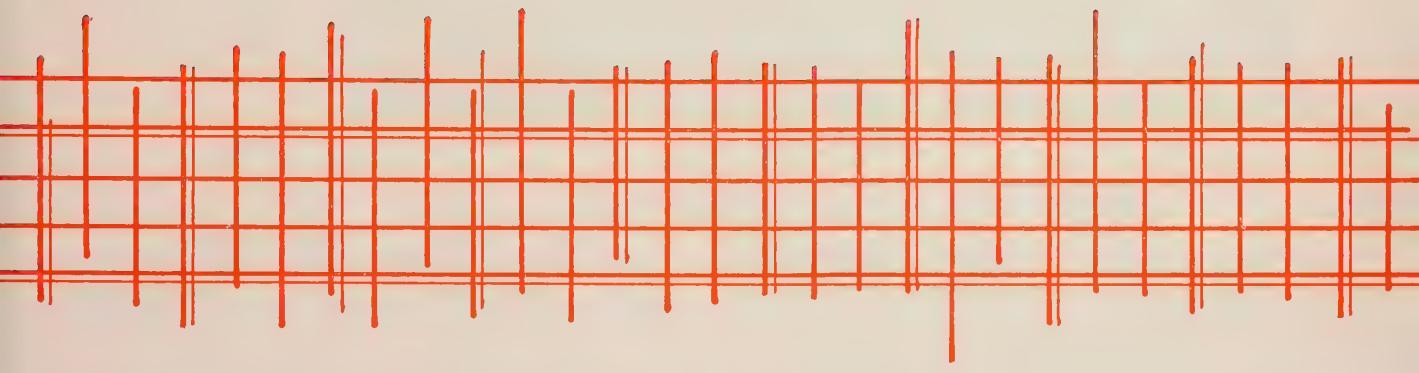

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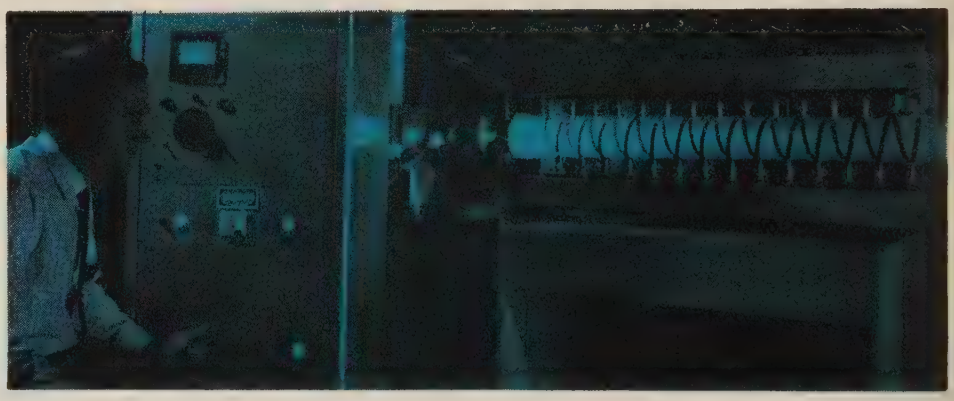
O.K. WITH INDUSTRY: So long as the non-profit organizations advising the military stick strictly to "thinking," as apparently does this group at Aerospace Corp., the aerospace industry leaders are willing to accept them.

Why industry fears

NON-PROFIT COMPETITION

NOT O.K. WITH INDUSTRY: Non-profit firms aren't able to stay away from hardware development and applied research (as in this test at STL's Physical Research Lab), industry leaders are afraid.



AEROSPACE CORPORATION has been on the receiving end for brickbats from two directions ever since it was set up in June 1960. Both industry and Congress have shown their disapproval in no uncertain terms. The unkindest cut of all came this year, when Congress lopped $5 million from $35.2 million requested by the Air Force for the non-profit company.

Actually, all "non-profit corporations" providing technical and advisory services to the military are under attack. Industry objects to them as "intruders" guilty on two counts:

- Instead of just 'thinking," they tend to go on to developing new systems and even "list articles," drying up competition.
- They have raided other firms for top-grade scientific, engineering, and legal talent, offering far higher salaries for the same jobs.

Congressional opposition claims that the military services are using non-profit firms to evade government salary scales and other Civil Service regulations. Some of it also asserts that the non-profit firms have led to a situation in which decisions affecting the government are being made by people who are not in government.

The top-level people in the aerospace industry admit, however, that non-profit firms like Aerospace and Mitre are needed. They make no bones about the fact that neither they nor the Air Force were prepared for the dramatic changes in the aerospace technologies that we have witnessed since World War II. Neither had the technical competence to do the necessary job of evaluation and management.

When the Air Force, for instance, finally realized what it was up against, it was too late. Hampered by civil-service pay restrictions, it no longer could get the scientists it so desperately needed, and it had no choice but to contract out the technical management of its ballistic missile programs to Space Technology Lab (then a division of Ramo-Wooldridge).

STL was the half-way house on the Air Force's road to Aerospace. Two things were "wrong" with it:

- It was the creature of a private, profit-seeking company.

by Randolph Hawthorne, Editor

• It soon was doing more than managing—it was getting into R&D on components.

Despite its remarkable achievements, therefore, STL had to go. The situation today is that STL (phasing out) and Aerospace between them handle the technical management functions of the Air Force's missile and space systems. These functions, the Air Force maintains, are not suitable for transfer to industry—they require an "objective" organization that has no hardware interest and can resist pressures and resolve conflicts to preserve the integrity of systems and assure their delivery on schedule. As a non-profit firm staffed by highly competent technical people. Aerospace fills this bill, it is claimed.

But industry is suspicious of Aerospace, and points to what happened with STL. "The people at STL went way off base in the detail that they went into," says a top industry manager. "They went from policy to exact details. Then they designed hardware and built it."

Scientists want to "go make things"

Some industry managers believe that this was inevitable. They argue that almost all scientists, after some years of "thinking," feel they "must go make something." As one manager puts it, "They want a lab. It's human nature."

Aerospace will go the same way as STL, he believes. "The argument will be," he predicts " 'The only way to keep my people is to have labs and do development work.' "

Rand may have found a solution for this problem of "human nature": It expects its people to "think" for only three to four years. After that, they are encouraged to go back into industry and the lab.

No such plausible cure is in sight for another worry that besets industry when it looks at the non-profit firms—specifically when it looks at Mitre, which works for the Air Force on electronics. In the past, Mitre was limited to advising on technical matters and determining the direction that USAF systems design should take. But on the 425-L command and control system, the Air Force recently announced Mitre will be responsible as well for initial systems engineering, technical direction, and intersystem engineering.

Much the same, industry people point out, happened with Aerospace on Minuteman. The trend, they say, seems to be to turn contractors from basic system designers into mere implementers. Dr. Brockway McMillan, USAF's assistant secretary for R&D, actually has publicly predicted such a change—at least for electronic systems.

Who, then asks industry, will be responsible for a system in the future? Will the Air Force hold Aerospace responsible for Minuteman or Boeing—which had nothing to do with the advanced studies or the systems engineering? And what will happen to the competitive design approach? Is it safe to have only one organization—even a non-profit one—be the sole source of new ideas?

Aerospace denies that it will usurp the development of new designs. "Our function rather is to work closely with the Air Force in long-range planning, systems analysis, and system comparison studies," a spokesman explains. "We review ideas and concepts generated by both industry and government. Before proposals on a new system are made by industry, we would perhaps have provided the Air Force with technical criteria establishing the feasibility basis for requesting such proposals. In no sense does this function eliminate design competition or discourage industry from making proposals on its own initiative."

The Air Force bears out Aerospace. Says Robert Miedel, assistant to USAF's director of procurement: "The criteria which a system must meet would originate in the Air Force. When these criteria are established for any system, industry is asked for proposals."

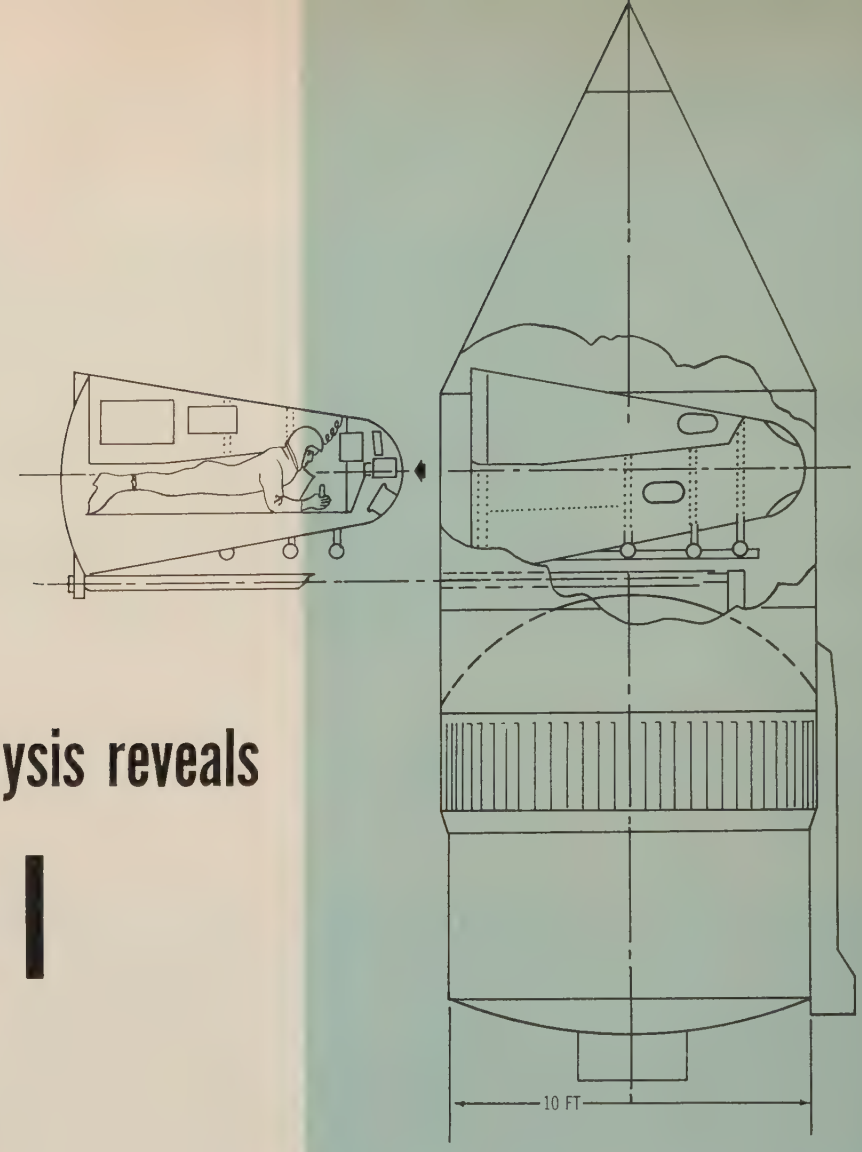
All this remains as it was before Aerospace came on the scene, he maintains. And on the 425-L system, no more actually happened, he asserts, than that Mitre was brought up to the Aerospace level. There is no intention of downgrading industry's role in R&D or in design proposals, Miedel explains.

Aerospace also points out that there are differences between its R&D and that done by industry: "We do conduct some research, both in areas requested by the Air Force and in others designed to maintain the technical competence of Aerospace personnel," a spokesman says. "We do not perform R&D work in the sense that the industry uses the term. To the contrary, the Aerospace technical management relationship with the Air Force is soundly based on the continued performance by industry of its R&D role." Furthermore, though Aerospace "integrates the designs of the various associate contractors and supervises system tests, it does not compete with them through the manufacture of anything."

Industry simmers over pirated talent

The non-profit firms have been very sensitive about the salaries they pay—probably because these are quite a bit higher than what industry pays. However, industry leaders don't fume so much over what the non-profit firms pay their staff. They are more upset by talent lured away before it is fully developed. This view will be hard to support, however, because there is hardly a man who doesn't think he is ready for bigger things before his supervisor does. And as to the pirating of personnel, who could cast the first stone?

Possibly the most serious charge against Aeropsace has been that its people make vital decisions that the government should make. The Air Force indignantly denies this charge. "Aerospace does not manage any of our programs," Under Secretary Dr. Joseph V. Charyk told Congress. "They assist in carrying out technical analyses and they offer technical recommendations with respect to certain elements of our programs. They do not make decisions as to these programs. These decisions are made by the Air Force."



PROBABLE configuration of Vostok I. The pilot capsule was ejected at the recovery altitude of 23,000 ft.

Computer analysis reveals

Vostok I design

OUR ANALYSIS of the Vostok I began with the definition of the vehicle's original orbit. The orbit eccentricity was computed from the known apogee altitudes (*Table I*) and in accordance with:

$$\epsilon_M = h_{AM} - h_{PM}/r_{AM} + r_{PM}$$

as 0.011, which means a very nearly circular orbit. It is reasonable to assume the Soviets would attempt to put the Vostok into a circular orbit, for this would make it simpler to determine the point of initiation of de-orbit and let them use a simplified retro-thrust system.

How nearly circular the Vostok orbit actually was can be shown by computing the maximum deviation from the local horizontal of the velocity vector. This maximum deviation, as well as the orbital point at which it occurred, can be found from:

$$\cos \phi = -\epsilon.$$

For $\epsilon = 0.011$, the maximum deviation is 0.63 deg and occurs at central angles of 90.63 and 269.37 deg measured from perigee (*Fig. 1*). The velocity variation of the vehicle in orbit can be computed by finding the

* Research Laboratories Div., The Bendix Corp., Southfield, Mich.

Table I: Known Characteristics of Vostok I Flight

Weight	
Structure	1633 lb
Instrumentation	3250 lb
Jettisonable sealed cabin	5512 lb
Total	10,395 lb
Perigee	112.4 miles
Apogee	203 miles
Orbit inclination	64 deg 57 min
Time sequence	
Takeoff	9:07
Over Cape Horn	9:52
Over Africa	10:15
Start of braking	10:25
Re-entry into atmosphere	10:35
Landing	10:55
Orbital Time	89.1 min
Total flight time	108 min
Re-entry ground distance	8000 km

by G. A. Cornell, R. W. Duncan, W. H. Gruber and R. J. Ritchie,
Senior Mathematician, Mathematician, Head, Systems Analysis Group & Supervisory Mathematician, Research Laboratories Div., The Bendix Corp

maximum velocity at perigee and the minimum velocity at apogee:

$$V = [2\mu(1/r - \tfrac{1}{2}a)]^{1/2}, \qquad 2a = h_A + h_P + 2R_e.$$

Assuming that the launch vehicle was programed for a circular orbit, we can approximate the orbit injection angle and injection velocity error combinations by computing the difference between the actual vehicle velocity in the known elliptical orbit and the velocity required at that point for a circular orbit (V^*):

$$V_e = V_M - V^* = [2\mu(1/r_M - \tfrac{1}{2}a]^{1/2} - (\mu/r_M)^{1/2}.$$

The corresponding angular error B made by the velocity vector with the local horizontal is given by (*Fig. 1*):

$$\phi_E = \pi/2 - \beta_M = tan^{-1}\left(\frac{1 + \epsilon_M \cos\theta_o}{\epsilon_M \sin\theta_o}\right) - \pi/2.$$

The sole major aspect of the original orbit that remains to be found are the orientations of the major axis of the orbital ellipse with respect to the launch and impact point within Russia. With the available data, this orientation can only be defined on the basis of the re-entry trajectory, which of course must satisfy the ΔV condition and agree with the ground distance

IN BRIEF

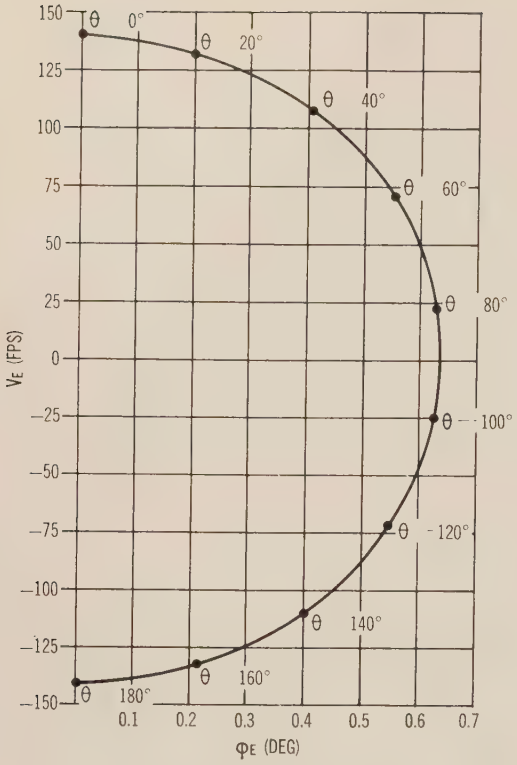
Scarce as they were, the official Soviet data on the Vostok I flight of last April 12, which made Maj. Yuri A. Gagarin the first man to go into orbit, provided enough information for a computer analysis of most of the basic aspects of Gagarin's vehicle. This report covers the most important steps in this analysis—original orbit, most of the de-orbit phase, and the atmospheric re-entry phase—and presents the data on orbital braking, retro-thrust system, launch system, impact accuracy, vehicle configuration, orbital orientation, peak re-entry decelerations, re-entry heating profile, and recovery system derived from the complete analysis.

Nomenclature

a	semi-major axis
C_s	specific heat (slugs$^{1/2}$/ft)
H_s	heat input (btu/sq ft)
h	altitude ($r - R_e$)
R_e	mean radius of earth
R_G	ground track, or distance
r	focal radius ($h + R_e$)
T_{RE}	stagnation equilibrium temperature (deg R)
t	time from start of re-entry
V	tangential velocity
$\dot{V}$	deceleration
V^*	velocity required at a given point for a circular orbit
β	angle of radius vector with respect to velocity vector
ϵ	eccentricity of orbit
θ	central angle subtended at the earth's center with respect to the de-orbit point
μ	product of gravitational constant and earth's mass
ρ	density
σ	radius of curvature of re-entry body's nose (ft)
ϕ	angle between velocity vector and local horizontal
ψ	angle between major axis and radius vector through the impact point

Subscripts

A	apogee
ATM	atmospheric re-entry
E	error
M	original orbit
o	de-orbit point, or point common to original orbit and re-entry trajectory
P	perigee



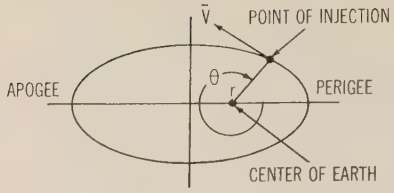


FIGURE 1: Combinations of injection angle and velocity errors for the Vostok I's non-circular orbit.

covered during, and the time taken by, the complete re-entry.

Our re-entry trajectory analysis was arbitrarily divided into three phases: de-orbit, atmosphere re-entry, and recovery (*Fig. 2*). From the analysis of the de-orbit phase, we derived a set of admissible trajectories that satisfied the required end conditions and this set was then reduced by the analyses of the other two phases.

Table I shows the end conditions we had to work with: the nominal time from start of braking to atmospheric re-entry (t_{ATM}) of ten minutes and the total ground distance covered during the complete re-entry of 8000 km, which corresponds to a central angle variation (θ_{ATM}-θ_o) of 72.09 deg. A further restriction is imposed by the re-

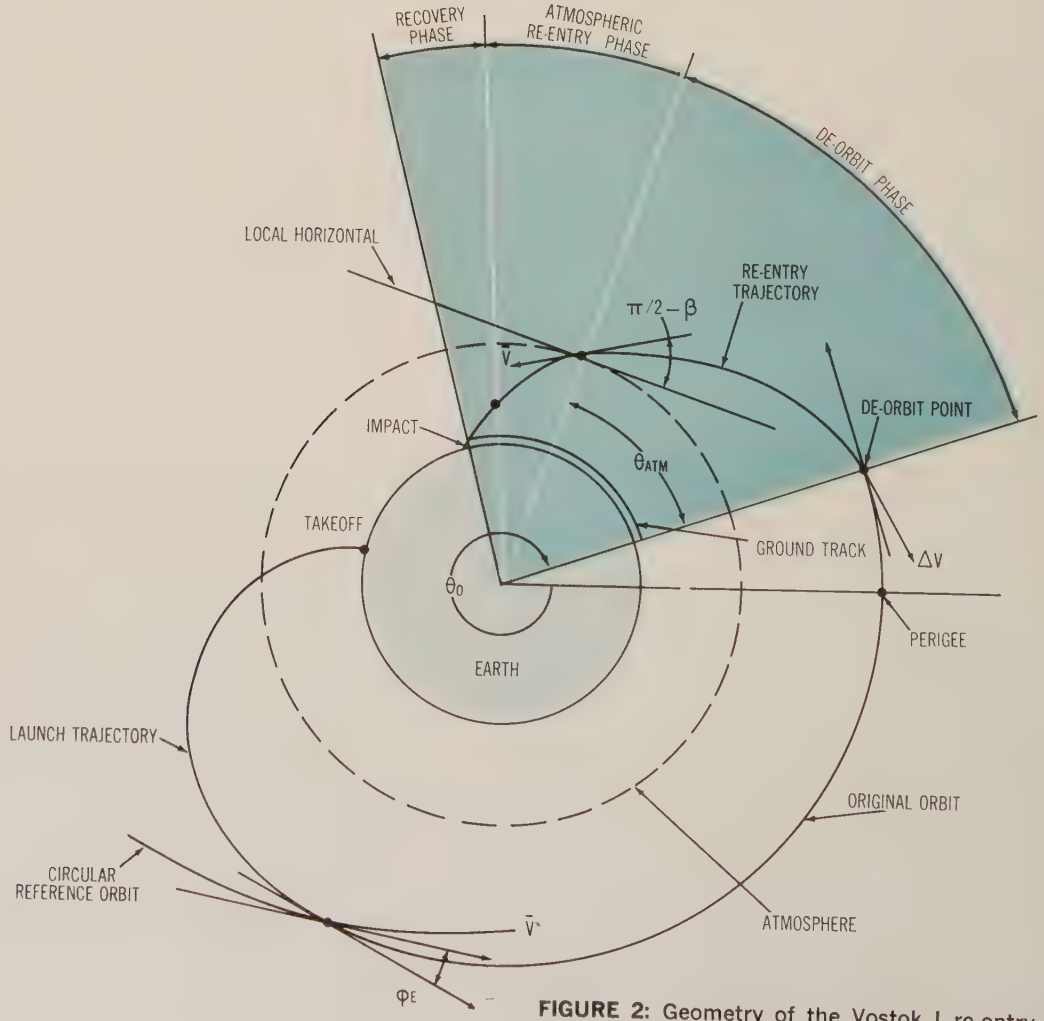


FIGURE 2: Geometry of the Vostok I re-entry analysis.

quirement that the atmospheric re-entry angle ($\lambda/2 - \beta$) —at the arbitrarily assumed atmospheric re-entry altitude of 60 miles—be less than 3.5 deg to keep deceleration and heating during atmospheric re-entry within acceptable limits.

To define the de-orbit phase, we considered the effects of three values of ΔV (corresponding to increments of impulsive thrust) as applied around the original satellite orbit: 440, 587, and 733 fps. We assumed that thrust was applied in the direction opposite to that of the velocity vector as defined by the original orbit, and for this assumption our three values of ΔV bracket the admissible set of re-entry trajectories. At any higher ΔV, the re-entry angle becomes excessive; at any smaller ΔV, both the time to atmospheric re-entry and the central angle variation become too large (*Fig. 3*). *Table II* shows the admissible re-entry trajectories finally derived from our de-orbit analysis.

Accuracies found from error analysis

Next we estimated the thrust and duration of the Vostok's retro-rocket, and performed an error analysis to find the accuracies required in velocity, velocity orientation, and vehicle location immediately after firing of the retro-rockets. The effect of errors in these quantities on impact accuracy was then found and related to errors in observation (which enter because the retro-rockets were fired by ground command based on tracking data) and retro-rocket control. For an assumed allowable miss distance, we then could derive the required tracking and retro-rocket control accuracies.

In computing the trajectories for the atmospheric re-entry phase, we assumed a spherical earth and a two-dimensional orbit and re-entry path. To the requirements of the de-orbit phase, we added two new ones: the peak deceleration during re-entry had to be less than 10 g and the total time for the de-orbit and atmospheric re-entry phases was to be about 20 minutes (leaving about 10 minutes for the parachute recovery phase).

The analysis of the atmospheric re-entry phase showed that each of the three values of ΔV used in our de-orbit calculations satisfied all requirements except peak V at only two values of θ_o (with respect to the perigee of the original orbit), yielding a reduced set of six admissible re-entry trajectories (*Table III & Fig. 4.*)[1] For these trajectories, the deceleration peaks are of relatively short duration (*Fig. 5*). Maximum deceleration, at $\Delta V = 733$ fps and $\theta_o = 206$ deg, corresponds to a re-entry angle of about 3.4 deg; minimum deceleration, at $\Delta V = 440$ fps and $\theta_o = 27.4$ deg, to a re-entry angle of about 1.31 deg.

Three of six trajectories eliminated

As we have restricted the allowable peak deceleration to less than 10 g, three of the six trajectories of *Table III* are eliminated, and we are left with $\Delta V = 440$ fps and $\theta_o = 27.4$ deg, $\Delta V = 440$ fps and $\theta_o = 110.5$ deg, and $\Delta V = 587$ fps and $\theta_o = 342.8$ deg. These trajectories are defined to the point at which recovery starts by the values for altitude and ground track (*Fig. 6*).

We now can go back and determine the orientation of the impact point with respect to the perigee of the

(1) This set must still be treated as a tool for design evaluation rather than as a clear-cut performance characteristic, since the original orbit, the system parameters assumed for the re-entry phase, and the end conditions noted are not completely described. Because the launching and re-entry system errors are random, statistical distributions would be needed for a complete description.

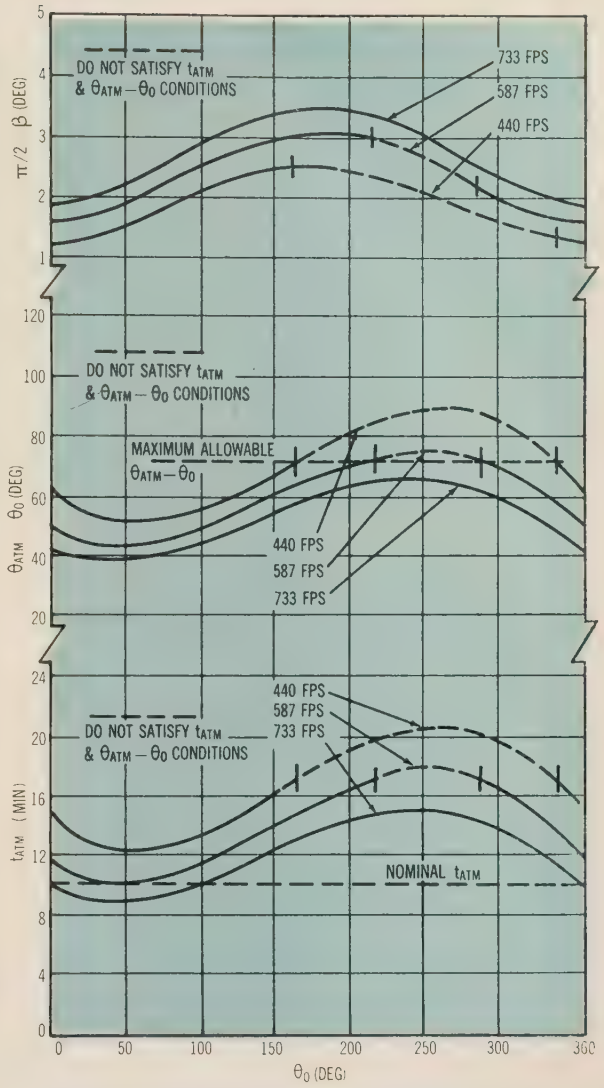


FIGURE 3: De-orbit point as a function of the re-entry angle (or the angle of the velocity vector at atmospheric re-entry with respect to the local horizontal), the variation in central angle during the de-orbit phase, and the duration of the de-orbit phase for the three values of ΔV used in the de-orbit analysis.

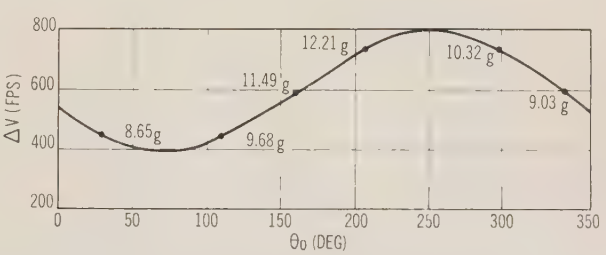


FIGURE 4: Range of de-orbit velocity increments satisfying θ_o-requirement of the de-orbit point. Peak deceleration values are given for the six admissible re-entry trajectories left after the analysis of the atmospheric re-entry phase. They show that three of these trajectories can be eliminated as exceeding the 10-g limit on V_{MAX}.

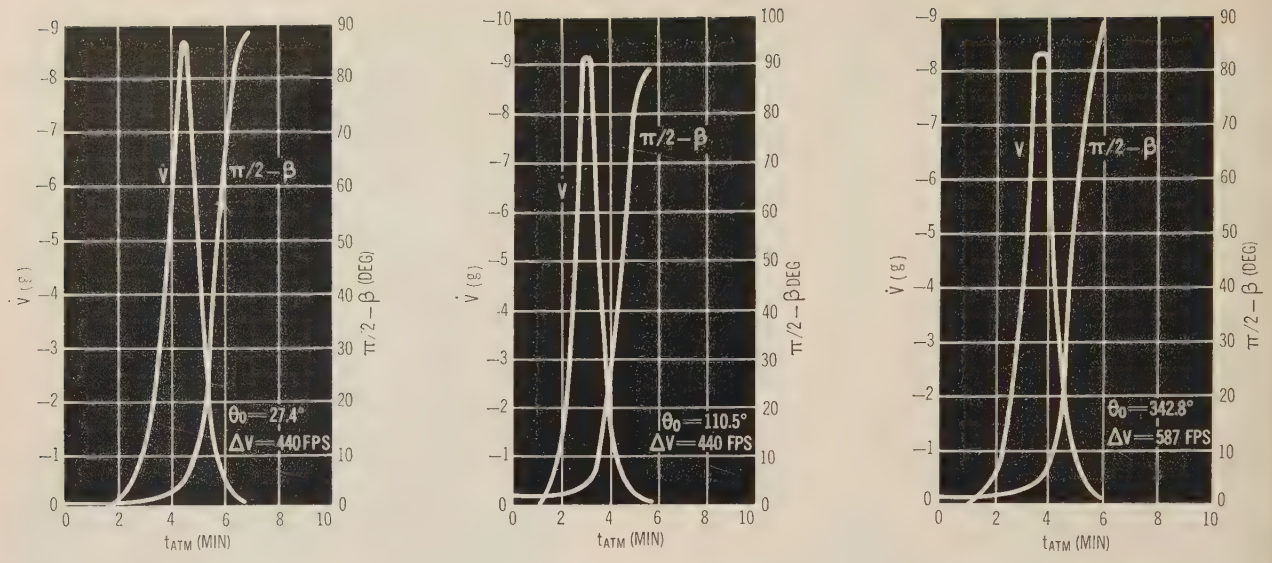


FIGURE 5: Time histories of the deceleration along the flight path and the flight path angle for the three admissible re-entry trajectories of Table III show relatively short deceleration peaks.

original orbit (*Fig. 7*), which is given by:

$$\psi = \theta_0 - 72 \text{ deg.}$$

For our three admissible re-entry trajectories we thus get 315.4, 38.5, and 270.8 deg.[2]

Heating profiles were determined

Our analysis of the atmospheric re-entry phase was completed by the determination of the heating profiles (*Fig. 8*). The stagnation heat transfer rate is given by:

$$dH_s/dt = C_s\sqrt{\rho/\sigma}V^3 \text{ btu/sq ft/sec.}$$

For the Vostok I, C_s can be estimated as 7×10^6 slug$^{1/2}$/ft and σ as 12 ft, so that we get:

$$dH_s/dt = 2 \times 10^6 \sqrt{\rho}V^3.$$

The stagnation equilibrium temperature is:

$$T_{RE} = (5000\rho^{1/8}V^3)^{1/4} \text{ deg R.}$$

The analysis of the recovery phase was based on the total of 30 minutes for the complete re-entry, an assumed 30-fps limit on impact velocity, and an assumed altitude of 23,000 ft for the start of recovery.

To satisfy these conditions, a parachute area of about 2750 sq ft is needed, which provides an impact velocity of about 27 fps (less than what is expected for the Mercury capsule). A drogue chute activated the main parachute to meet the further requirement of a nominal full chute deployment time of 10 seconds, which corresponds to a loading of about four g.

We now had the data we needed for an estimate of the Vostok I's system characteristics. We could assume that the Soviets wanted to have some control over the impact point. The precise original orbit and therefore the ΔV needed to hit a given impact area and the point at the orbit at which this ΔV had to be applied could not have been determined before launch. However, we know that the Russians had the tracking stations necessary for determining the original orbit after launch. Thus it's reasonable to assume (as we have done) that the de-orbit phase was begun on signal from a ground

(2) For this orientation, too, a statistical distribution would be needed in an exhaustive performance analysis.

Table II:
Definition of Re-entry Trajectories after De-Orbit Phase Analysis

ΔV (fps)	θ_0 (deg)
733	$0 \leq \theta_0 \leq 360$
587	$0 \leq \theta_0 \leq 220$
587	$290 \leq \theta_0 \leq 360$
440	$0 \leq \theta_0 \leq 165$
440	$340 \leq \theta_0 \leq 360$

Table III:
Definition of Re-Entry Trajectories after Atmospheric Re-Entry Analysis

ΔV (fps)	θ_0 (deg)
440	27.4
440	110.5
587*	158.7*
587	342.8
733*	206.6*
733*	297.4*

* Eliminated because of excessive g-loading.

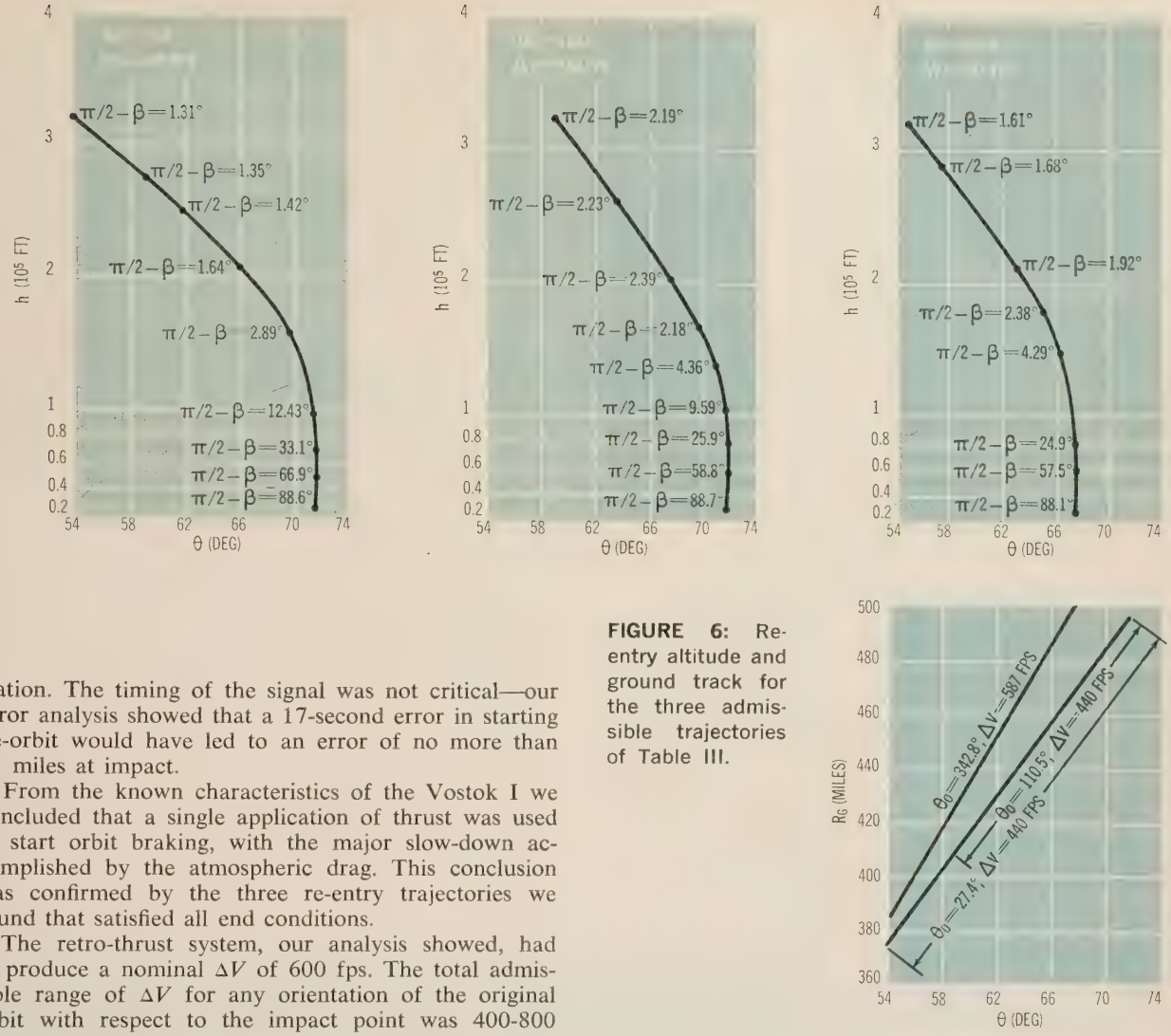


FIGURE 6: Re-entry altitude and ground track for the three admissible trajectories of Table III.

station. The timing of the signal was not critical—our error analysis showed that a 17-second error in starting de-orbit would have led to an error of no more than 81 miles at impact.

From the known characteristics of the Vostok I we concluded that a single application of thrust was used to start orbit braking, with the major slow-down accomplished by the atmospheric drag. This conclusion was confirmed by the three re-entry trajectories we found that satisfied all end conditions.

The retro-thrust system, our analysis showed, had to produce a nominal ΔV of 600 fps. The total admissible range of ΔV for any orientation of the original orbit with respect to the impact point was 400-800 fps. If the peak deceleration during atmospheric re-entry is restricted to less than 10 g, this range shrinks to 400-550 fps.

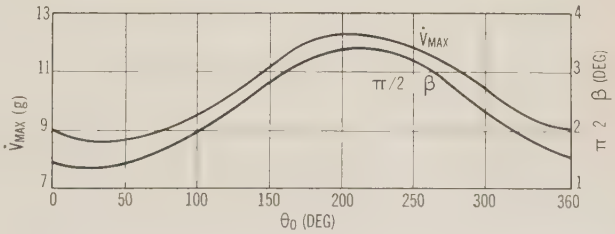
These ΔV values apply for a retro-thrust opposite to the orientation of the velocity vector, an assumption that is borne out by the fact that the Vostock achieved a very nearly circular orbit and that its velocity vector never deviated by more than 0.6 deg from the local horizontal. (Assuming no error in the alignment control itself, this accuracy could be obtained with a simple horizon scanning device.)

Total impulse of 138,250 lb-sec

For a ΔV of 440 fps (from one of our three admissible re-entry trajectories) and a specific impulse of 250 sec, we got a propellant weight of 553 lb and a total impulse of 138,250 lb-sec. The duration of thrust we estimated at more than three seconds and the overall weight of the retro-thrust system at 10-15 per cent of the overall vehicle weight, or about 1000-1500 lb. Finally, because of the safety margin needed to offset expected deviations in the launching and re-entry systems, we could reasonably assume that the retro-thrust system was able to impart a range of velocity increments to the re-entry vehicle.

On the basis of the Vostok I's actual orbit, we found the maximum possible velocity and injection angle errors as 140 fps and 0.63 deg, respectively, so long as they did not occur simultaneously, and set the nominal values of these errors at 100 fps and 0.45 deg. These quantities, of course, are elements of a statistical population, which cannot be defined without additional samples. We could assume, though, that the Russians had at least a 95 per cent chance of achieving a Vostok I orbit that differed from a circular orbit by less than one degree in injection angle and less than one per cent in velocity.

It was also reasonable to assume that the injection angle and velocity errors were independent and nor-



PEAK DECELERATION during re-entry and re-entry angle vs central angle of the de-orbit point.

mally distributed (with means zero and V_o and standard deviations). The standard deviations then were 0.447 deg and 111.4 fps, and the Russians could expect to do better than the nominal errors of 0.45 deg and 100 fps 43 per cent of the time.

Our error analysis showed that, while the expected errors in timing and orbital position yielded negligible impact errors, errors in the retro-thrust vectors and in measuring the orbital altitude produced appreciable impact errors—a one-degree error and a 13-mile altitude error would have led to impact errors of 30 and 115 miles, respectively. By far the most sensitive parameters were the velocity orientation and velocity magnitude at the de-orbit point. A 25 fps error in measuring the velocity and a 0.75-deg error in measuring the velocity orientation each would have resulted in an impact error of 115 miles. Assuming that the Russians wanted to impact within a given area with a probability of 0.95, these two errors plus the 13-mile altitude error would have required a circular impact area with a 500-mile radius.

Retro-thrust accuracy better than 5%

The critical factors for impact accuracy therefore were the ground control center's ability to measure velocity magnitude and orientation and the retro-thrust system's ability to provide the necessary ΔV. If we assume a nominal ΔV of 600 fps, the retro-thrust system had to be accurate to better than five per cent to fulfill the impact conditions we have set up.

We considered re-entry trajectories for both lift and non-lift vehicles. In most cases, lift resulted in an excessive re-entry angle if the end conditions were to be satisfied. (This was to be expected, since lift reduces the rate of descent and increases the ground distance from de-orbit to impact.) We therefore excluded the possibility of a lift vehicle.

That the Vostok I did not have lift is made highly probable by the fact that the Soviet timetable for space flight includes lunar missions. For a lunar descent from orbit, lift cannot be used. In view of the Russians' clear tendency to use the same basic vehicle design (in successively more sophisticated versions) for a wide range of missions, this also indicates what can be assumed of a Soviet vehicle for terrestrial re-entry.

Pilot re-entered in prone position

The peak deceleration values we found indicate that the pilot was oriented in an optimum manner to withstand the re-entry g-forces—with the g-force presented to the pilot from chest to back.

To derive a re-entry heating profile we chose a representative trajectory. The maximum heat transfer, we calculated, was 41 btu/sq ft/sec and occurred at an altitude of 170,000 ft. For a drag area of 25π sq ft, the maximum heat transfer at this altitude is 3218 btu/sec, while the maximum stagnation temperature at 170,000 ft is 2600 deg F.

On the basis of this heating profile, we concluded that little internal cooling was used. Most of the re-entry heating effects probably were absorbed by an ablative shield and the shock wave of a blunt-nosed re-entry vehicle. This conclusion is supported by the fact that the pilot's capsule could be ejected in case the temperature of the complete top-stage assembly became excessive.

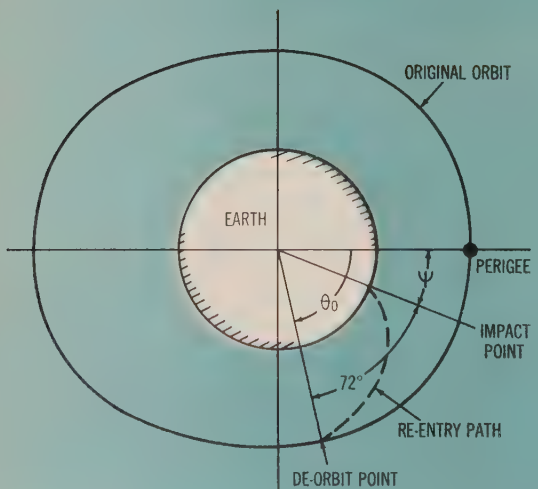


FIGURE 7: Geometry defining the orientation of the impact point with respect to the perigee of the original orbit.

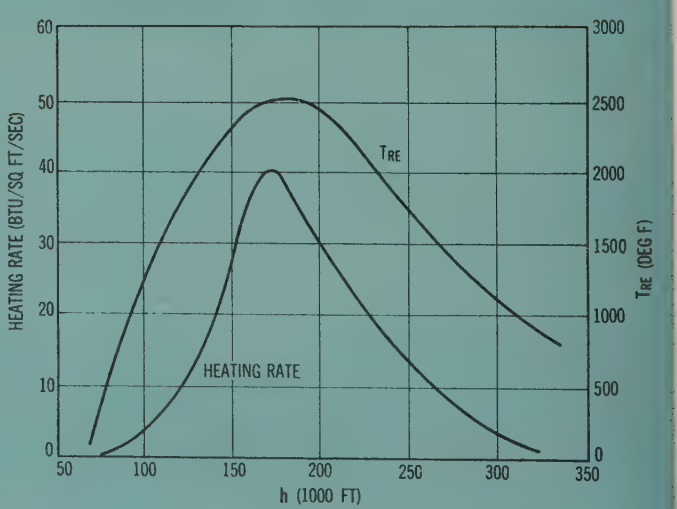


FIGURE 8: Heating rate and stagnation temperature vs altitude for a representative admissible re-entry trajectory.

Analytic approach to stretch-forming cuts time and cost

by Claude F. Morris, Jr., Manufacturing Research Engineer, General Dynamics/Ft. Worth*

THE B-58 PRODUCTION program left little time for the formability evaluation of structural materials. In place of the traditional trial-and-error investigation, our Applied Manufacturing Research and Process Development Department therefore decided on an analytical approach to stretch-forming and set up a research program to derive the necessary equations. These have proved so effective for aluminum parts that they are now being extended to materials like the titanium alloys and stainless steels.

Natural-log or true stress-strain curves based on tensile and compressive test coupons offer excellent insights into metal behavior. True stress-strain curves take into account the reduction or increase of the cross-sectional area of the coupons, which is a key factor in metal forming, and can—if obtained for a variety of temperatures, heat-treats, and strain rates—describe with great accuracy the limiting effective stress and strains.

By applying these limiting values to the equations expressing the forming operations, the formability limits of a material can be found. Many other factors, of course, complicate the problem—variables in tool clearances, materials, operators, machines, and even in the stress-strain curve—but this approach provides a basis for further studies.

Finding the formability limits analytically reduces long and expensive test programs to a short series of verification tests. Of course, many materials are extremely anisotropic and have large Bauschinger effects, and these properties must be taken into account. Also, many sheet-metal forming machines lack proper controls for pinpointing stress and strain levels, which are needed when you work from the forming equations. In our case, the installation of Sheridan Gray and Hufford elongation control systems on our sectional stretch presses made it possible to use the analytical approach.

These elongation control systems allow only a predetermined amount of strain in the material. Stress variations from one part to another of the same materials are eliminated—the machines use whatever force is needed for the preset amount of strain.

These control systems also make it possible to shift the neutral axis from within the part to a position out-

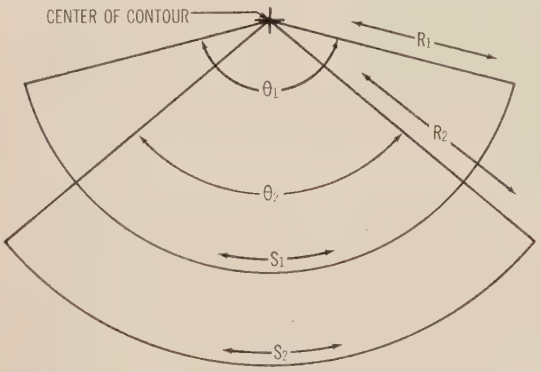
*General Dynamics/Ft. Worth, Grant's Lane, Ft. Worth, Texas.

IN BRIEF

As time between preliminary design and hardware has been shrinking, manufacturing R&D has had to find quicker ways of evaluating the fabrication properties of materials. An obvious fast method is the analytical approach. This article reports how such an approach, leading to spring-back-allowance equations, was worked out for the stretch-forming of B-58 aluminum parts and, in combination with elongation control, cut production costs by up to 50 per cent.

Nomenclature

E_e	elastic elongation
E_m	maximum allowable elongation for stretch-forming
E_o	plastic elongation
R_1	die and material radius in tension
R_2	material radius with no tension
S_o	original material length
S_1	stretch material length in tension
S_2	stretch material length with no tension
θ_1	included angle of material in tension
θ_2	included angle of material with no tension



side the part. Therefore, the part is in tension throughout, and there is no danger of compressive buckling due to compressive strains. Part uniformity and improved quality are two immediate results of this approach.

The controls play an even more important role, though, in solving the problem of conflicting heat-treat and ductility requirements. Most airframe detail parts require heat treatment if they are to attain their proper strength levels. Unfortunately, in the heat-treated condition materials often don't have enough ductility for stretch-forming to the desired configuration. Aluminum alloys, for instance, typically must be stretch-formed in a more ductile state and heat-treated afterwards. In the course of this heat-treat, they are stress-relieved, and distortion results, so a finish-stretch-form operation is needed to obtain the final configuration. Obviously, a good deal of money would be saved if only one forming operation were required.

Specifically, aluminum alloys remain in the unstable W-condition after the heat-treat cycle if kept under refrigeration. In this condition they have (aside from slight losses) the same properties as in the annealed O-condition. They can be stretch-formed to the desired configuration and then allowed to air-harden to the heat-treated T-condition. However, springback due to elastic strains will again distort the part, so that it is still not sufficiently formed.

Trial and error is impractical

The whole problem would disappear if the stretch-form die could have a springback allowance. Finding this allowance by trial-and-error methods can become prohibitively expensive. With elongation controls, through, the amount of strain placed in the part is known beforehand. The amount of elastic strain therefore can be found by an analysis of the true tensile stress-strain curve. Correlating the elastic and plastic strains with the geometric description of the forming operation then answers the question, "How much should the stretch form be altered to allow springback?"

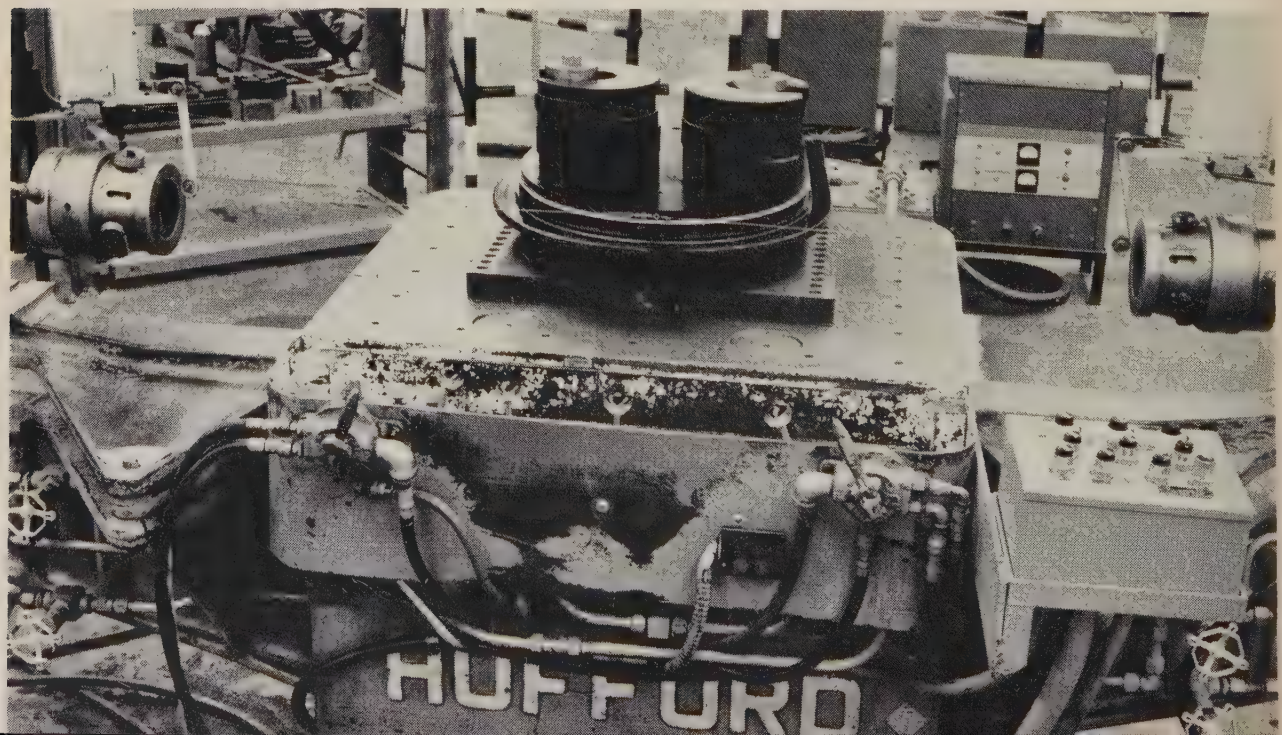
The springback equation we have derived (see *Box*) has proved very accurate on production parts. The derivation is straightforward and uncomplicated and the simplifications we have used in it have been justified by the end results.

Our working equation is:

$$\Delta R = R_s(E_m - E_o - 2E_o)/(2 + E_m + E_o).$$

With parts that have several radii, it is applied to each

STRETCH-PRESS setup showing stretch form with springback allowance and elongation control system.



Analysis of Springback Allowance for Aluminum Stretch-Forming

Basic Relationships

$S_1 = S_o(1 + E_o + E_e)$ or $F(S_1) = S_o$
$S_2 = S_o(1 + E_o)$ or $G(S_2) = S_o$

Procedure

Step 1: From the geometric relationship $R\theta = S$:

$$\Delta R = R_2 - R_1 = S_2/\theta_2 - S_1/\theta_1,$$

where ΔR is the amount to be removed from R_2 to allow for springback.

Step 2: Empirical expression for $F(\theta_1) = \theta_2$:

$$\theta_1 \approx \theta_2 [1 + (E_m - E_o)/2]$$

Step 3: Therefore:

$$\Delta R = \frac{S_2}{\theta_2} - \frac{S_1}{\theta_2(1 + K)} = \frac{S_2(1 + K) - S_1}{\theta_2(1 + K)}$$

where $K = (E_m - E_o)/2$

Step 4: Substitution of $F(S_1) = S_o$ and $G(S_2) = S_o$:

$$\Delta R = \frac{S_o(1 + E_o)(1 + K) - S_o(1 + E_o + E_e)}{\theta_2(1 + K)}$$

$$= \frac{S_o[(1 + E_o)(1 + K) - (1 + E_o + E_e)]}{\theta_2(1 + K)}$$

Step 5: Multiplication and simplification:

$$\Delta R = \frac{S_o(1 + K + E_o + KE_o - 1 - E_o - E_e)}{\theta_2(1 + K)}$$

$$= \frac{S_o[K(1 + E_o) - E_e]}{\theta_2(1 + K)}$$

Step 6: Substitution of $G(S_2) = S_o$:

$$\Delta R = \frac{S_2[K(1 + E_o) - E_e]}{\theta_2(1 + K)(1 + E_o)}$$

$$= \frac{R_2[K(1 + E_o) - E_e]}{(1 + K)(1 + E_o)}$$

Step 7: Resubstitution of $E_m - E_o/2 = K$:

$$\Delta R = \frac{R_2[(E_m - E_o)/2(1 + E_o) - E_e]}{[1 + (E_m - E_o)/2](1 + E_o)}$$

$$= \frac{R_2[(E_m - E_o)(1 + E_o) - 2E_e]}{(2 + E_m - E_o)(1 + E_o)}$$

Step 8: Multiplication:

$$\Delta R = \frac{R_2(E_m + E_mE_o - 2E_eE_m - E_o - E_o^2 - 2E_e)}{(2 + 2E_o + E_m + E_mE_o - E_o - E_o^2)}$$

Step 9: Simplification and removal of the second-order terms:

$$\Delta R = R_2(E_m - E_o - 2E_e)/(2 + E_m + E_o)$$

radius in turn. The centers of the radii are then reblended along common tangent lines of radii to provide the springback allowance contour.

As the equation shows, the only data that are needed are the elastic maximum stretch-forming strain and the radius or radii of the finished part. The preset strain is chosen arbitrarily— usually as the minimum amount needed to insure plastic tensile strains throughout the part. The maximum stretch-forming strain can be found from the true stress-strain curve, depending on the desired amount of cross-sectional reduction. The elastic strain is then found from the true stress-strain curve and the "preset" strain.

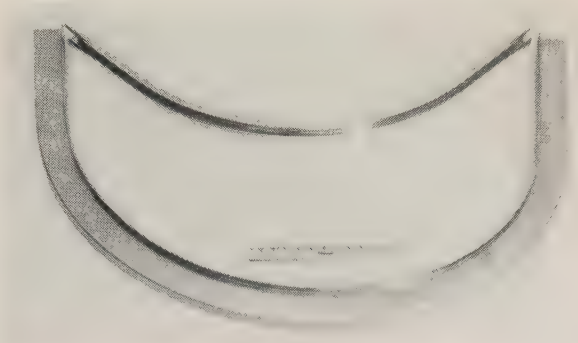
Curve gives effective-strain

In working with our equations, the distinction between strain and elongation must be kept in mind. The values used in the equation are elongation values, but the values obtained from a true stress-strain curve are effective-strain values. Elongation is the increase of dimension along one axis of a part, while strain is the summation of dimensional change along three axes (assuming an orthogonal system) at a given point.

In the elastic range, Poisson's ratio of ⅓ is generally used to convert strain to elongation. For the plastic range, a "pseudo-Poisson" ratio of ½ is used.

Many B-58 aluminum parts are being stretch-formed in one operation to net contour on tooling using springback-allowance stretch-form dies and elongation control systems. Manhours per part have dropped sharply as a result, leading to savings of up to 50 per cent. Our maximum stretch-forming elongation limit for 2024-W is 14 per cent. The preset elongation is usually one per cent. Stretch-form die friction can be reduced either by lubricants or by an occasional jarring of the die while the part is being formed.

ALUMINUM parts stretch-formed to net size in the W-condition in one operation using springback-allowance stretch forms and elongation controls.



RESEARCH REPORT

Beryllium

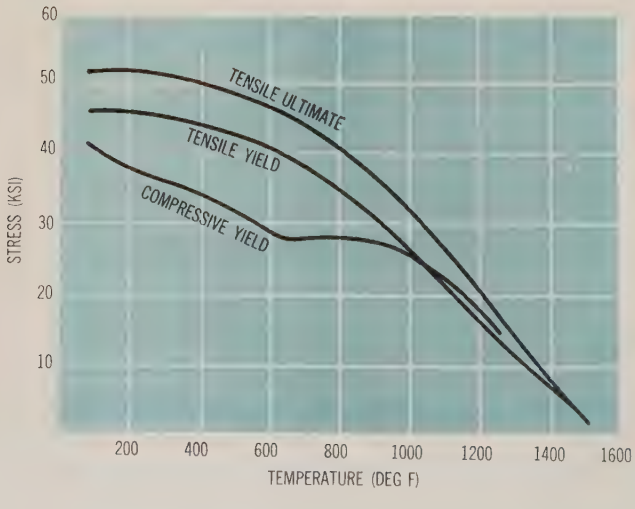
for aerospace structures

by L. A. Riedinger, Assistant Manager, Structures, Lockheed Missiles & Space Co

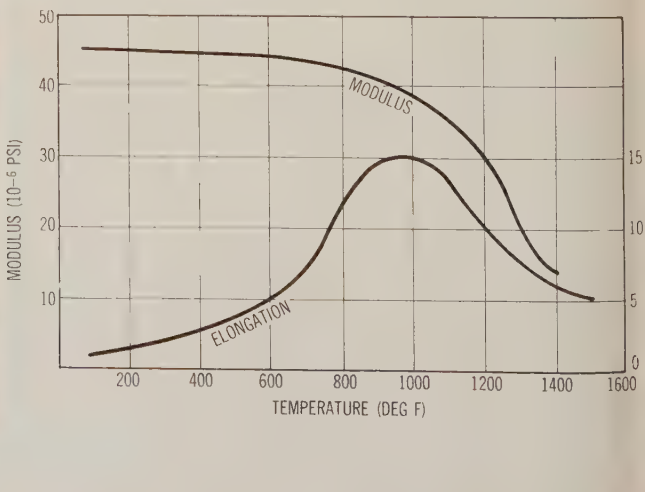
As seems to happen with every new "miracle metal" that comes along, there has been a letdown on beryllium. Now that the first excitement over this metal's attractive basic properties has passed, the development problems seem to loom extra-large. Due primarily to brittleness and high cost, these problems are indeed serious, but they can be overcome if we go on to learn just how beryllium can best be used in aerospace structures. Once we are able to perform meaningful structural optimization analyses, have reliable design data and fabrication methods, and have defined the metal's advantages and cost in terms of specific applications, beryllium will take its place as a major structural material.

Because of the need for further data on beryllium in aerospace applications, Lockheed Missiles & Space Co., Sunnyvale, Calif., is working — partly under contract to USAF—on a comprehensive structural evaluation of beryllium. This report (condensed from a paper, "Beryllium as a Structural Material for Aircraft, Missiles and Spacecraft," given at the Institute of Metals, in London, England, last October) summarizes the results to date of this evaluation.

Block: Strength vs Temperature

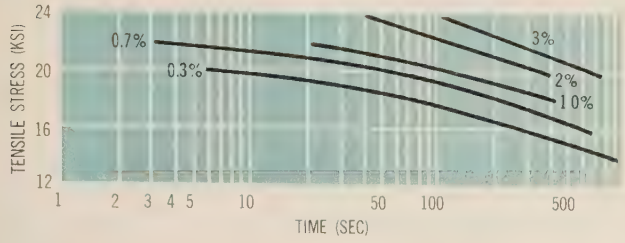


Modulus and Elongation vs Temperature

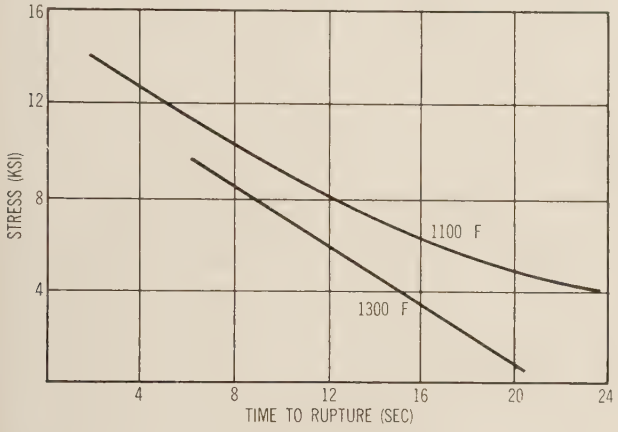


QMV Block: Creep

At 1000 deg F for 1.85 per cent BeO content.

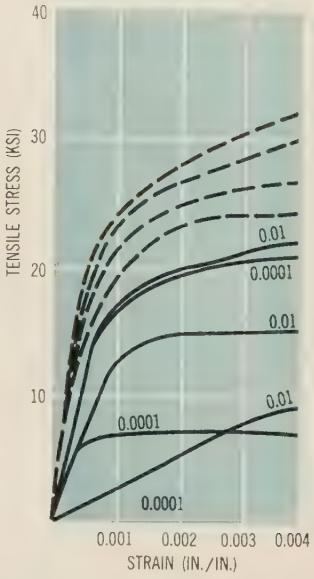


Stress Rupture



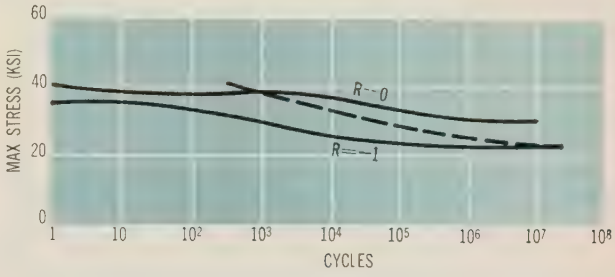
QMV Block: Stress vs Strain

At various strain rates, 150 deg F/sec heating rate and for 1.85 per cent BeO content. Dashed curves are based on strain rates of both 0.01 and 0.0001 in. / in. / sec.



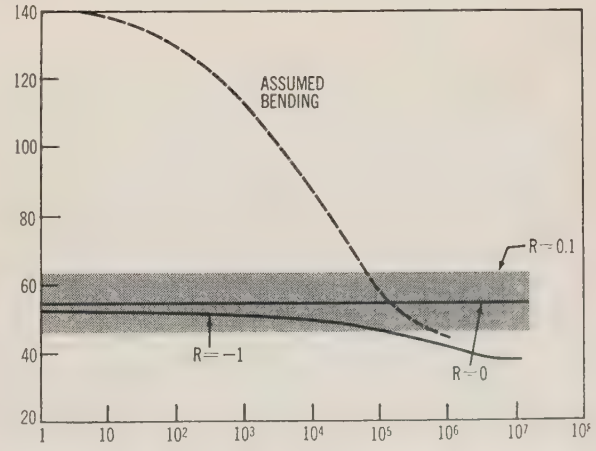
QMV Block: Fatigue

For axial loading at two ratios (R) of minimum to maximum stress (solid curves) and for bending of rotating beams (dashed curve).



Sheet: Fatigue

For axial loading at various ratios (R) of minimum to maximum stress and under various surface conditions (band).



Structural Evaluation of Beryllium at Lockheed

Tests of Notch Sensitivity, Bi-Axial Strength, and Fracture Strength

Notch-sensitivity tests: block (35 specimens); sheet (35 specimens)
Bi-axial-strength tests: block; sheet (bend tests at 2:1 bi-axiality, 8 specimens)
Post-buckling compression and shear strength tests: Flat
Flat plates: elastic buckling (6 specimens); plastic buckling (3 specimens)
Circular cylinders: axially loaded (3 specimens); under lateral pressure (1 specimen)
Sandwich panels: (2 specimens)

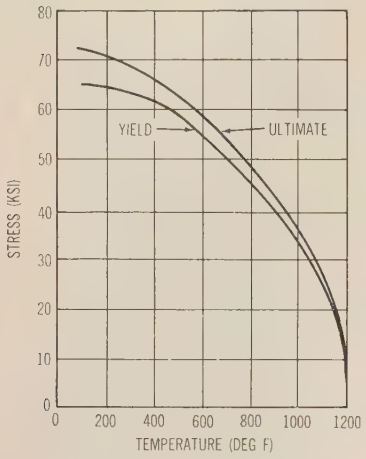
Structural Optimization Tests

Tests of the more familiar, basic structural components made of beryllium. Wherever possible, experimentally verified test methods are used.

Optimum-Design Studies of Beryllium Sandwich Components

Flat compression panels
Flat shear panels
Wide columns
Box beams
Axially loaded cylinders
Torsionally loaded cylinders
Cylinders under radial crushing pressure

Sheet: Strength vs Temperature

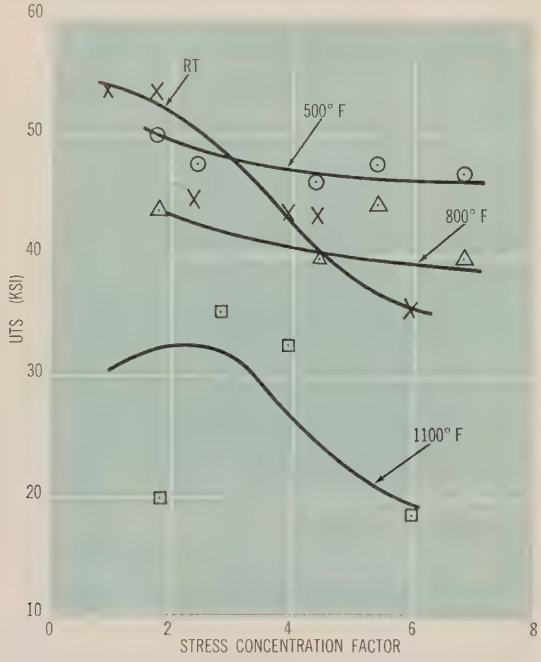


For cross - rolled, 0.125 - in. - thick Brush QMV sheet containing 1.85 per cent BeO.

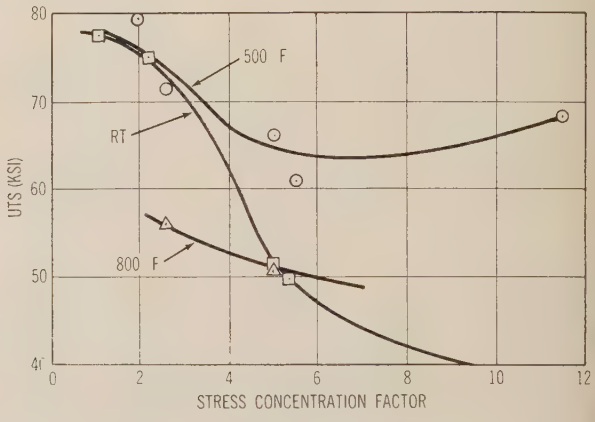
Recommendations for Future Beryllium Research

- Complete testing of newly developed sheet as it becomes available
- Tests to verify optimum design calculations
- Further tests and studies of bi-axial yield and fracture strength
- Fabrication studies for beryllium sheet

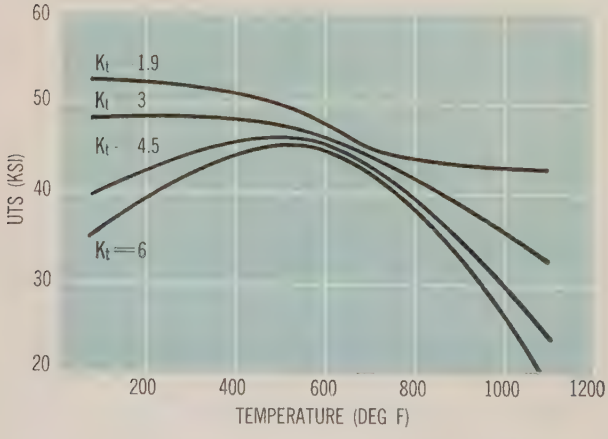
QMV Block:
Notch Sensitivity vs Temperature



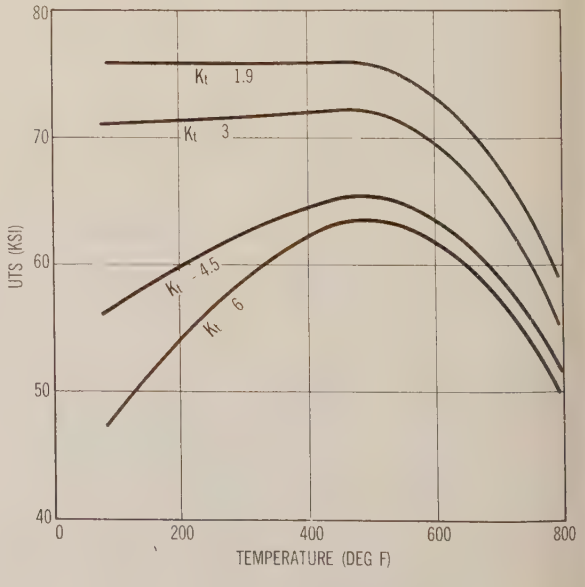
Rolled Sheet:
Notch Sensitivity vs Temperature



QMV Block:
Temperature vs Stress Concentration
For notched bars at various stress concentration factors.



Rolled Sheet:
Temperature vs Stress Concentration
For notched specimens at various stress concentration factors.

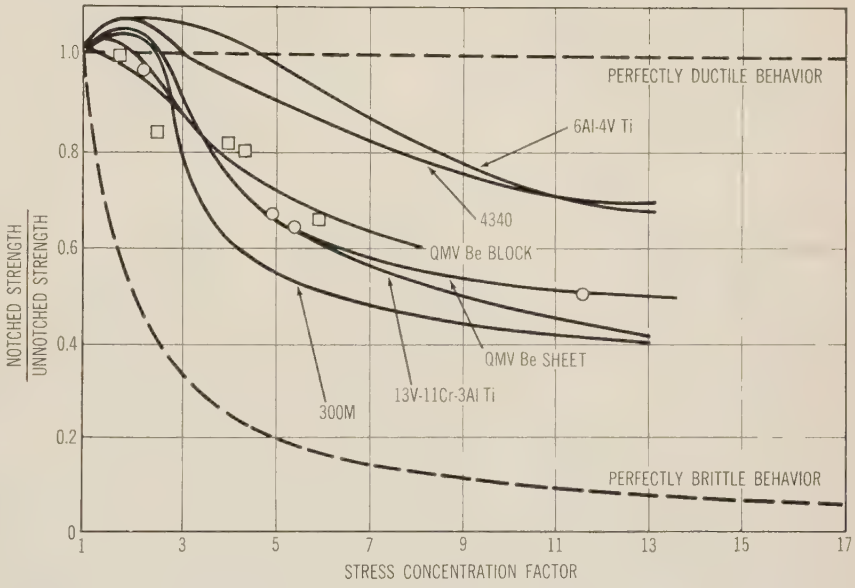


Future Applications of Beryllium

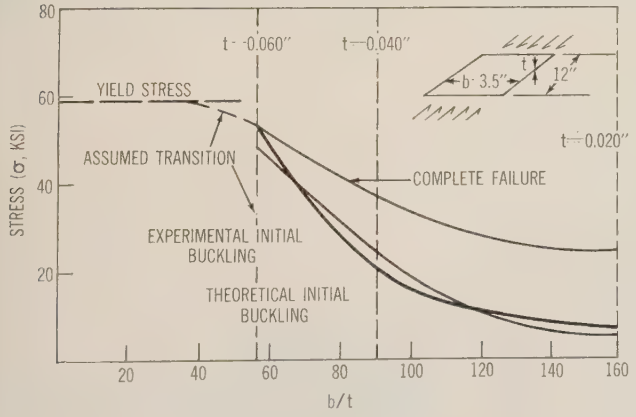
	Immediate Future		Farther Future
	Aircraft	Missiles & Spacecraft	
Primarily as structure	leading edges; secondary wing skins, some fuselage plating (within limits set by acoustic fatigue), control surfaces	interconnect structures of upper stages, noise shells, internal top-stage structures	torsional restraint structures for tank clusters; multi-wall structures for space platforms, re-entry structures (except for very-high-temperature components), wing empennage & fuselage structures, insulated or cooled internal structure where temperature control is mandatory
Primarily as heat sink	fuselage noses, inlet ducts, brakes, multi-wall crew enclosure structures	multi-wall payload enclosure structures, heat shields for parachute recovery vehicles (e.g., Mercury)	internal cabins of re-entry vehicles, certain parachute-recovered orbital capsules
Other applications		gyros, gears, linkages & bellcranks, insulation, brackets	

Comparison of Room-Temperature Notch Strengths

	Ultimate Stress (ksi)
300M	310
4340 steel	250
13V-11Cr-3Al Ti	200
6Al-4V Ti	170
QMV Be sheet	77.8
QMV Be block	53.5

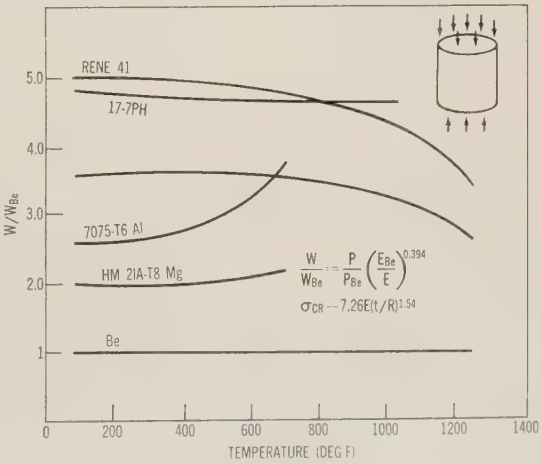


Thin Sheet: Buckling Allowable



Comparison of Weights

For axially compressed cylindrical shells.



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Significantly higher strength-weight ratios. Structures wound with the new BAKELITE epoxy resins have greatly increased flexural, tensile and edgewise compressive strengths . . . well in excess of Specification MIL-R-9300A, Type I. *and—tensile elongation as high as 7%!*

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Samples available: For detailed information and samples of the new, improved BAKELITE epoxy filament winding resins, ERL-2256, ERL-2258, and ERL-0500, contact your nearest Union Carbide Plastics Technical Representative, or write: Dept. LC-129L, Union Carbide Plastics Company, Division of Union Carbide Corporation, 270 Park Ave., New York 17. *In Canada:* Union Carbide Canada Limited, Toronto 12.

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No. 24 on Reader Service Card

Blue Streak

now slated for satellite launches

by Christopher Dawson
Associate Editor

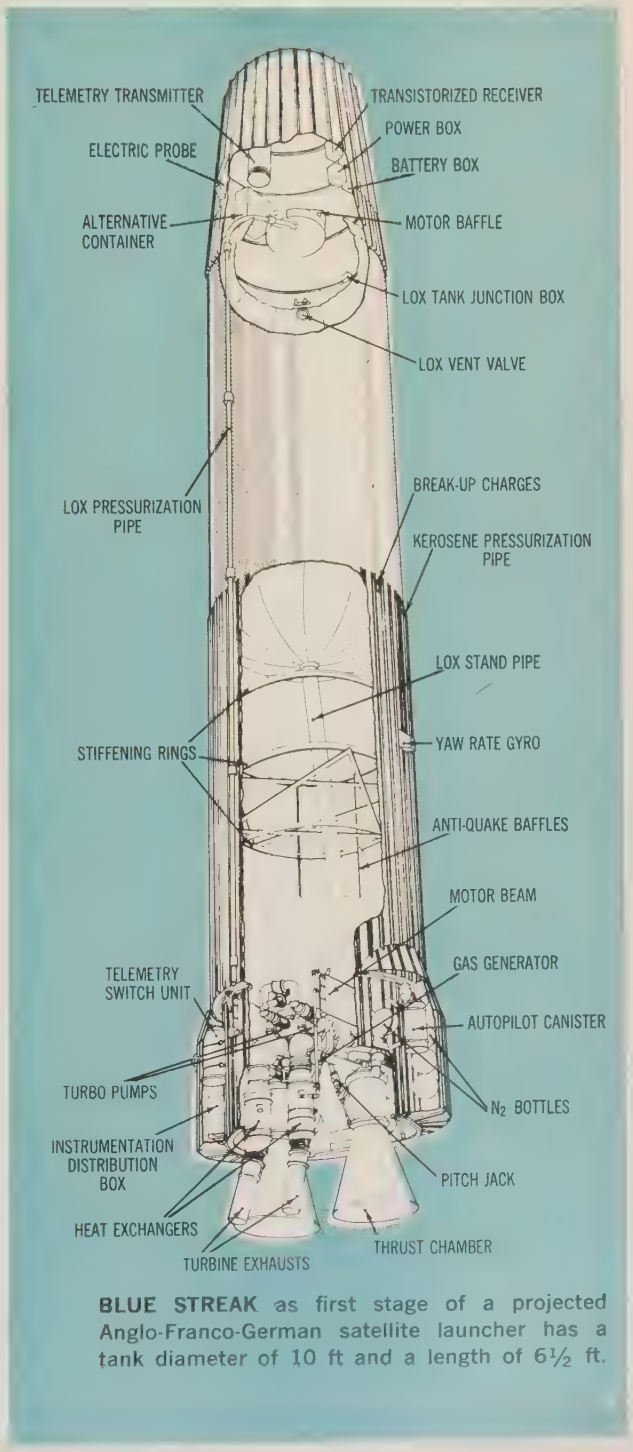
THE BLUE STREAK started out in 1955 as a ballistic missile with a range of some 2500 miles. De Havilland Aircraft, Hatfield, Herts., was the prime contractor, and Rolls-Royce was to develop the liquid-propulsion system. To save development time, the two companies made exchange-of-information agreements with General Dynamics/Astronautics and Rocketdyne, respectively.

In 1960, when the Blue Streak was within about a year of its first launch, the British government decided that fixed launching sites were too much of a handicap for a deterrent and the project was cancelled. However, when pressure was brought to bear to keep the Blue Streak going as the first stage of a satellite launcher, the government agreed to do so, provided other European countries joined the project. France subsequently agreed to develop a second stage, West Germany has taken on the third and final stage, and the new project seems to be well underway.

The Blue Streak is comparable to the Atlas, except that it is slightly smaller and has two engines, both burning lox and kerosene, instead of two boosters and a sustainer. As a missile it was to have been a single-stage vehicle with auto-pilot and inertial guidance. Exactly what changes will be needed to adapt it to its launcher role has not yet been decided. The inertial guidance system (developed by Sperry Gyroscope Co. Ltd.)

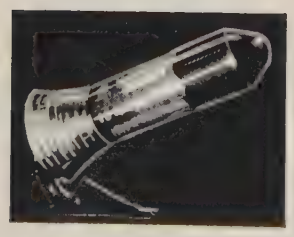
IN BRIEF

Europe's most ambitious spacecraft design to date is the British Blue Streak, originally conceived as a single-stage ballistic missile and now to be used as the first stage of a satellite launcher. In many respects similar to the Atlas ICBM, it uses a thin-gauge stainless structure and two lox-kerosene engines of 150,000 lb thrust each. In addition to structure and propulsion system, this report also covers the major subsystems of the Blue Streak.



BLUE STREAK as first stage of a projected Anglo-Franco-German satellite launcher has a tank diameter of 10 ft and a length of 6½ ft.

HITCO-
developed
fabrication
techniques
are
now
providing
portions
of
the
heat shield
for
production
Atlas
and
Titan
nose cones



ABLATIVE MATERIALS ENABLE FIRST ICBM NOSE CONE RECOVERY
This RVX1-5 was the first nose cone to travel full ICBM range and be successfully recovered intact. Speeds up to 15,000 mph, temperatures to 12,000°F, high heat inputs, and high acceleration and deceleration forces were encountered. The RVX1-5 was enabled to withstand these severe re-entry conditions through the use of REFRASIL[1] and AVCOITE[2] ablative heat shield materials.

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No. 25 on Reader Service Card

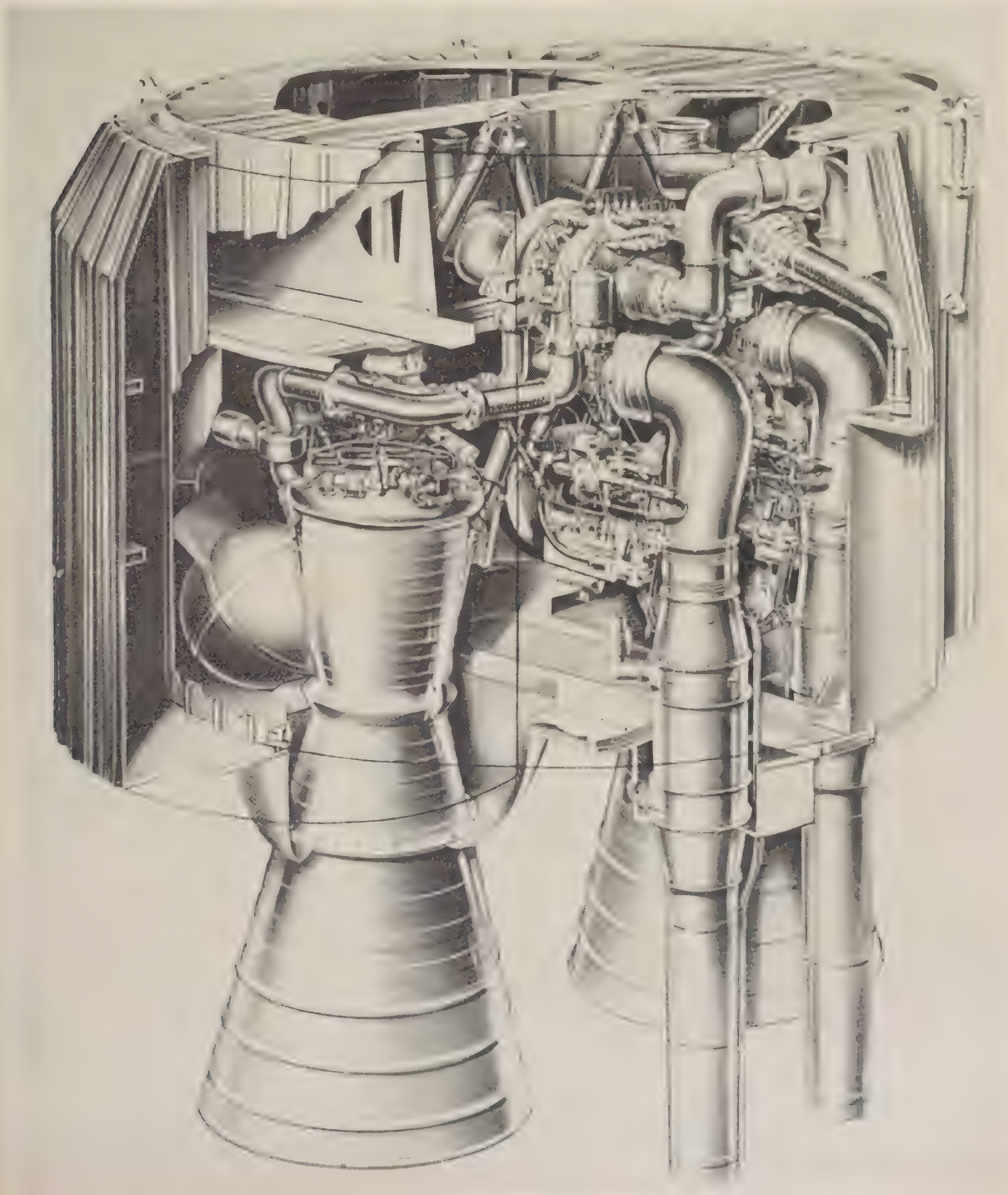
definitely has been abandoned to save weight, and command guidance will be used instead. Guidance bay and warhead support structures will be replaced by a separation bay.

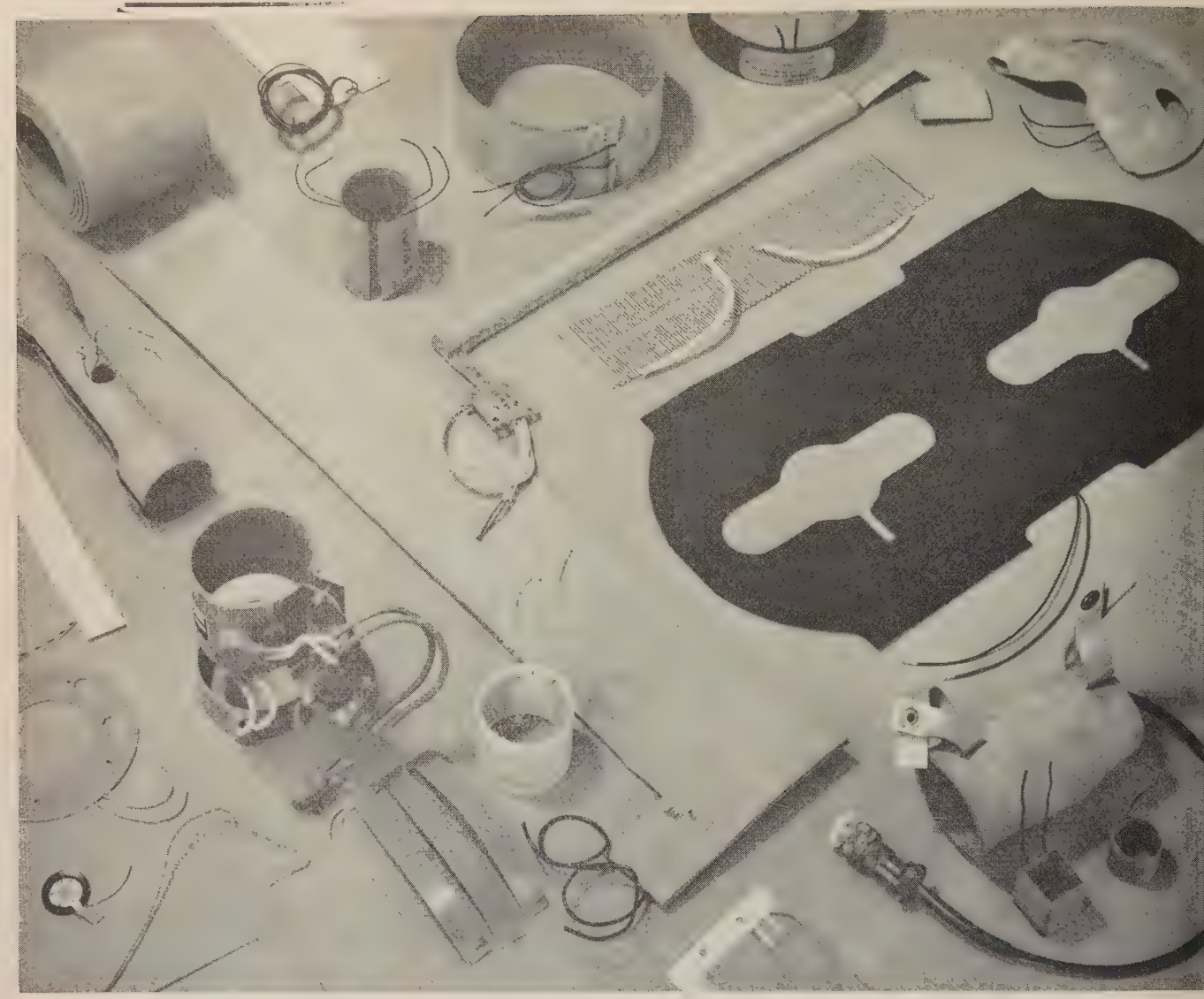
As on the Atlas, the tank structure is a thin-gauge, pressure-stabilized stainless steel shell. The lower kerosene tank, however, must be able to support the full tank and the nose structure even should its pressure be lost, and this bay therefore is strengthened by external top-hat-section stringers. The kerosene tank pressure at 11 psi is lower than the lox pressure, which is 26-30 psi, and the spherical diaphragm separating the tanks is concave forward.

The kerosene tank also has three internal stiffening rings to which non-structural anti-slosh baffles are fitted. The rings are lap-jointed to lugs welded on the inside of the skin, with a friction washer in between, and the securing bolts are spring-loaded. Tests had shown that the welded structure would have had little structural damping, and in this way damping is introduced without too much restraint. The middle ring frame is itself stiffened by a double-triangular truss to maintain the true circular shape in the "quaking" mode. The lox tank has no internal or external stiffeners.

The skin material is 17/7 stainless steel supplied at 160 KSI UTS in gauges from 0.010 in. up. Most of the skin is 0.019 in. thick; the heaviest stainless sheet is 0.035 in. thick. This sheet is supplied as 36-in.-wide

ASYMMETRIC arrangement is used in the Blue Streak's propulsion bay.





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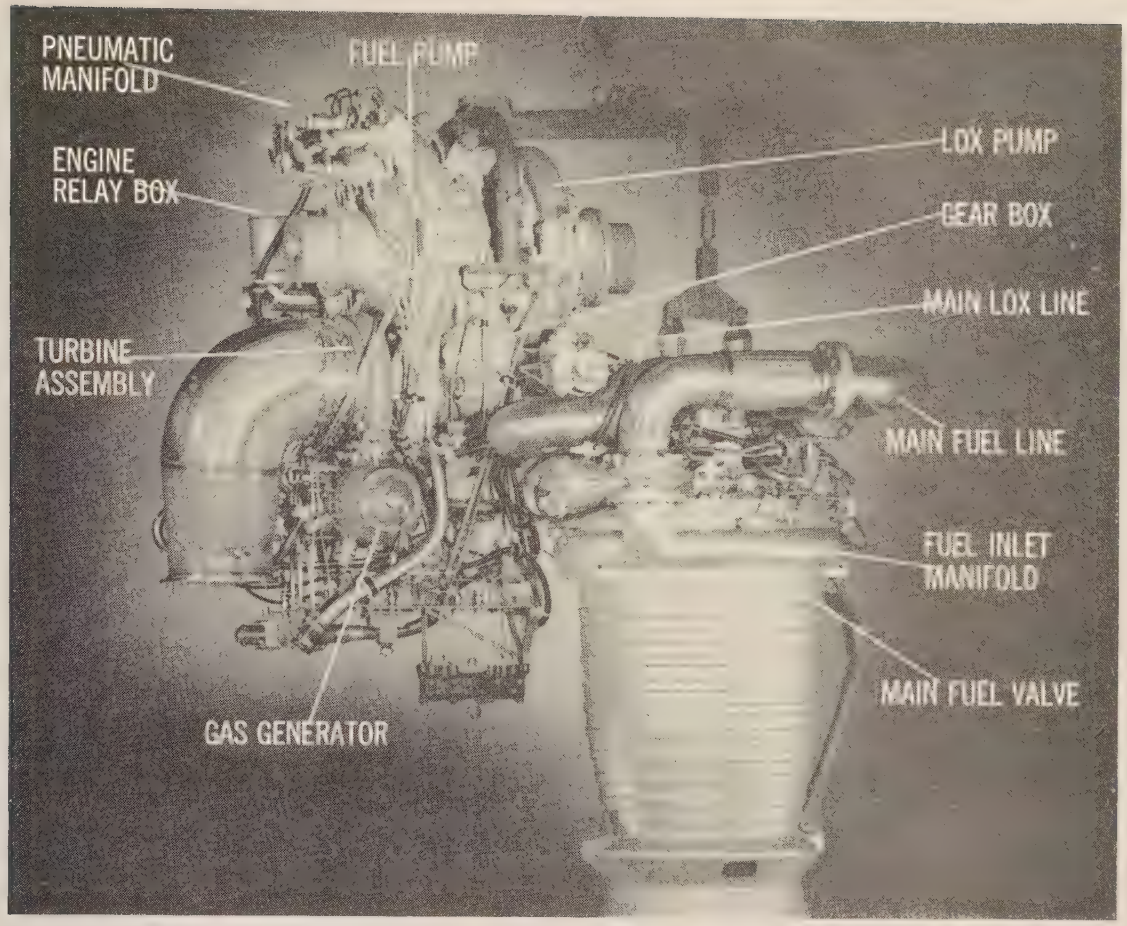


ROLLS-ROYCE RZ-2 lox-kerosene engine used on the Blue Streak.

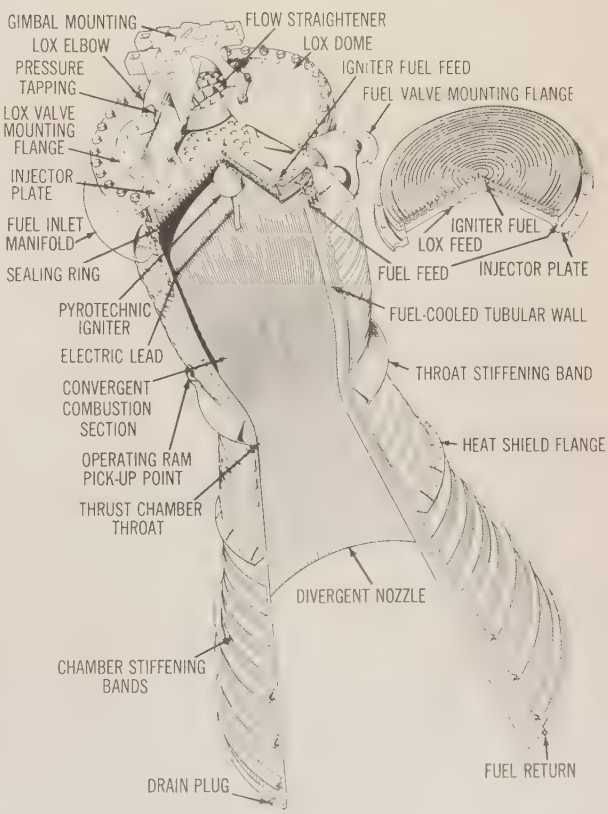
strip, cut diagonally, and butt-welded to form a ring. The butt weld is backed by a spot-welded strap.

The tank ends are closed by hemispheric domes. A double-walled standpipe carries through the kerosene tank. The cavity, vented to atmosphere, keeps kerosene from gumming.

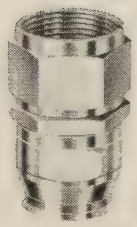
Open girder truss binds forgings

The main structure in the propulsion bay is a pair of fabricated light-alloy beams, ending with the forgings outside the skin. These forgings are tied together by an open girder truss in the plane of the thrust chamber axes. They also form the attachment points of the propulsion bay to the load diffusion structure at the base of the kerosene tank. The propulsion bay casing is mainly a fairing and is one foot smaller in diameter than the tanks. It also carried the bulky equipment pannier fairings. The lower part of the bay is closed by a heat shield.

The two Rolls-Royce RZ-2 engines, adapted and developed from the Rocketdyne S-3, eventually will have a sea-level thrust of 150,000 lb each for about 160 seconds. (More advanced versions were to have been developed for the missile design.)



THRUST CHAMBER of the RZ-2, which weighs about 760 lb. The holes in the injector plate (shown inverted) are angled in pairs for like-on-like impingement just over ½ in. from the plate face. ▶



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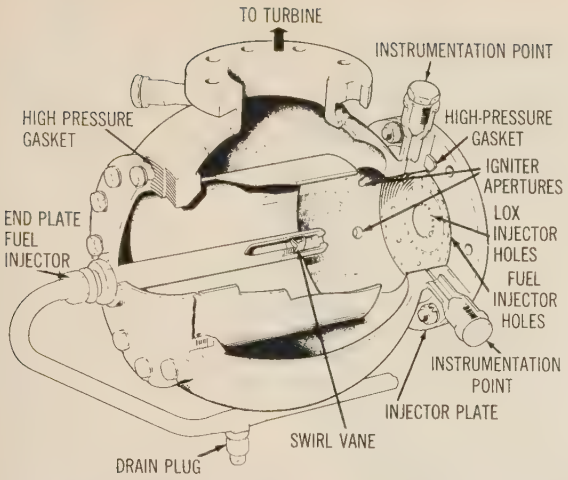
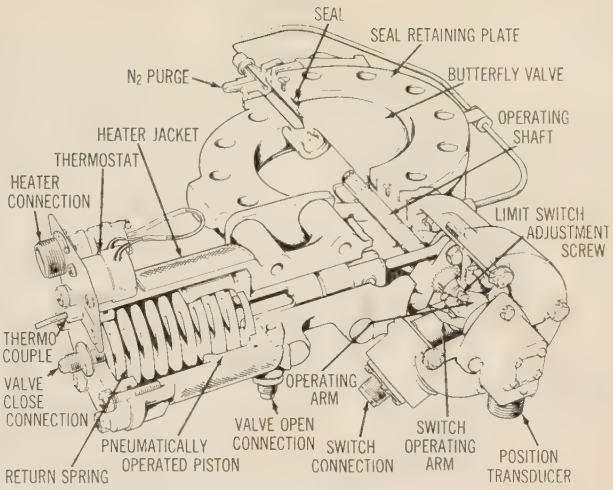




GAS GENERATOR (left) supplying pump turbine has inner chamber to insure mixing of the gas without hot spots. Ten per cent of kerosene flow through the generator passes through the central tube and is used for cooling. Right: Main lox valve has lip seal in PCTFE to prevent leakage under standby conditions.

The thrust chambers are each built up from 312 nickel tubes by bronzing. Tube wall thickness is 0.012 in. The rectangular section changes as necessary to conform to the chamber profile. Plain conic, divergent nozzles are used. For cooling almost the entire kerosene flow is being used. The area ratio of combustion zone to throat is 1.8; the exit-throat area ratio, 8. At 137,000 lb thrust, the chamber is at 544 psia and 3190 deg C. The inner-tube-wall temperatures range from 400 deg C in the chamber to 470 deg C at the throat.

The fuel injection pattern provides extra fuel for film cooling of the inner wall of the combustion zone. A drop of 150 deg C is produced at the inner wall by the thin carbon film forming on it. The propellants are injected into the chamber through concentric, alternating rings of fuel and lox jets.

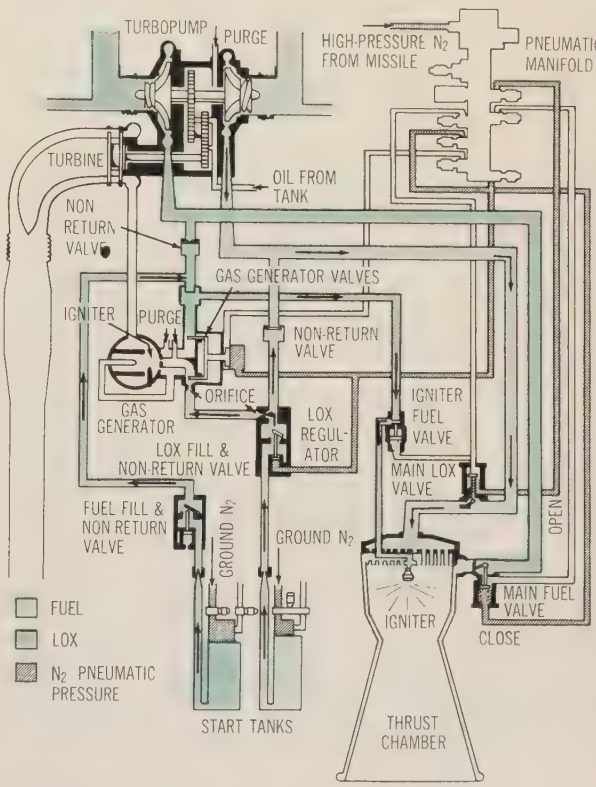
Turbine exhaust adds 500 lb thrust

Each engine has its own turbopump set, developing about 2400 hp at 30,000 rpm. Each turbine is supplied from a gas generator running at a kerosene weight ratio of about 0.35 to keep the gas temperature down to about 650 deg C. The exhaust from the turbines is discharged overboard, adding a total of 500 lb extra thrust. The exhaust pipes are swung outwards after lift-off in a lanyard-actuated movement to keep the flames clear of the bay.

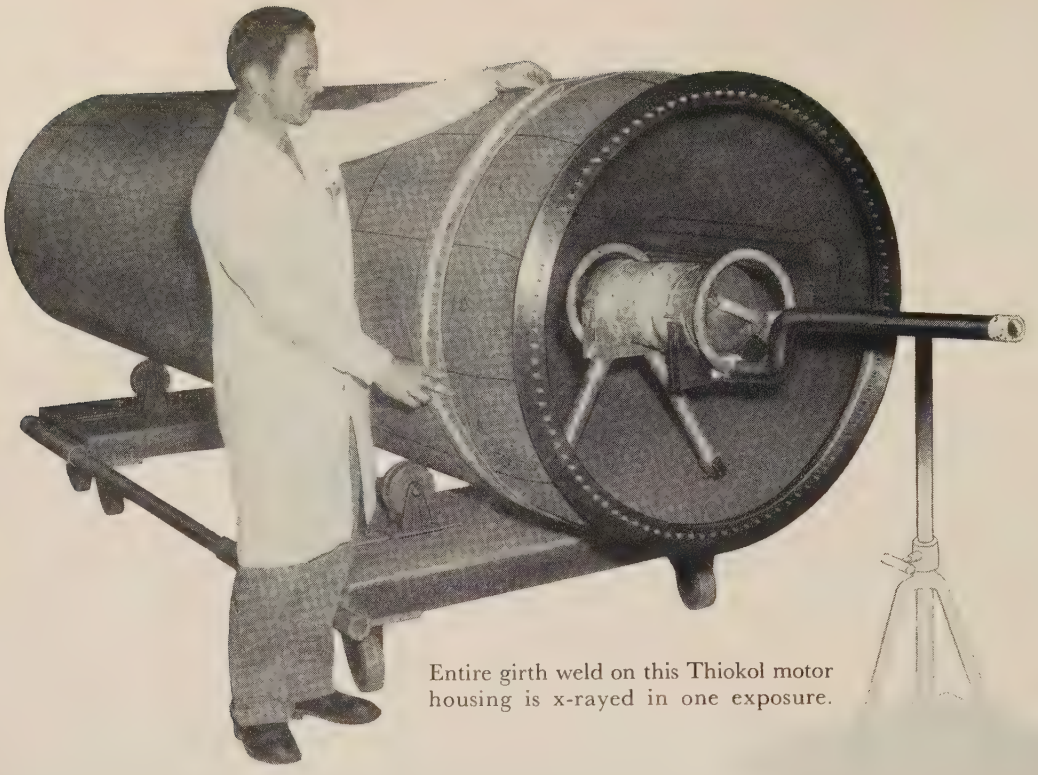
The command guidance will inject electric signals into the autopilot loops. Details of the autopilot system are still classified, but it is apparently fairly straightforward. As no aerodynamic derivatives are used for control, there is no need for varying the loop gains with altitude. Three rate gyros are mounted on the outside of the kerosene tank shell at experimentally determined nodal points. Except for gyros, the autopilot system is housed in the equipment panniers around the propulsion bay.

The 3000-psi hydraulic system for the combustion chamber actuators is supplied from Dowty Vardel pumps driven from the two turbopump assemblies via a power takeoff. The main fuel valves are actuated by an automatically sequenced electro-pneumatic system using gaseous nitrogen. After lift-off, this nitrogen is taken from six stainless bottles in the panniers.

There is also a liquid-nitrogen bottle with an inner stainless shell and an outer glass fiber-reinforced plastic one, the cavity between the two being filled with boiled-off nitrogen. The liquid nitrogen is used to pressurize the kerosene tank; it is evaporated in a heat exchanger on one of the turbopump exhaust lines before being fed to the tank. Lox is vaporized in the same way by an exchanger on the other exhaust to pressurize the oxidizer tank.



IGNITION flow pattern of the RZ-2 engine.



Entire girth weld on this Thiokol motor housing is x-rayed in one exposure.

For Thiokol's Redstone Division...

the metal parts countdown starts here

Right in the first stages of missile-motor processing, the Thiokol Chemical Corporation begins its countdown with a check—by radiography—of the soundness of each weld.

Putting power plants together for the nation's space program is intricate work.

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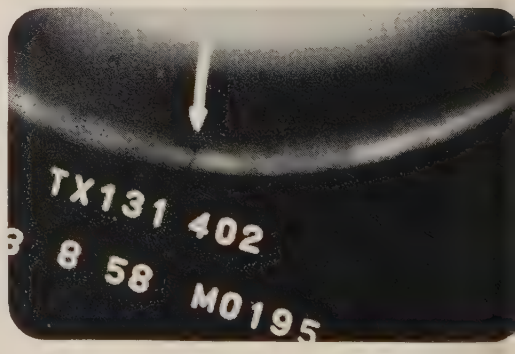

Arrow points to faulty weld caught on Kodak Industrial X-ray Film.

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Long-term orbit capsule for fifty-pound chimp

by Irwin Stambler, Associate Editor

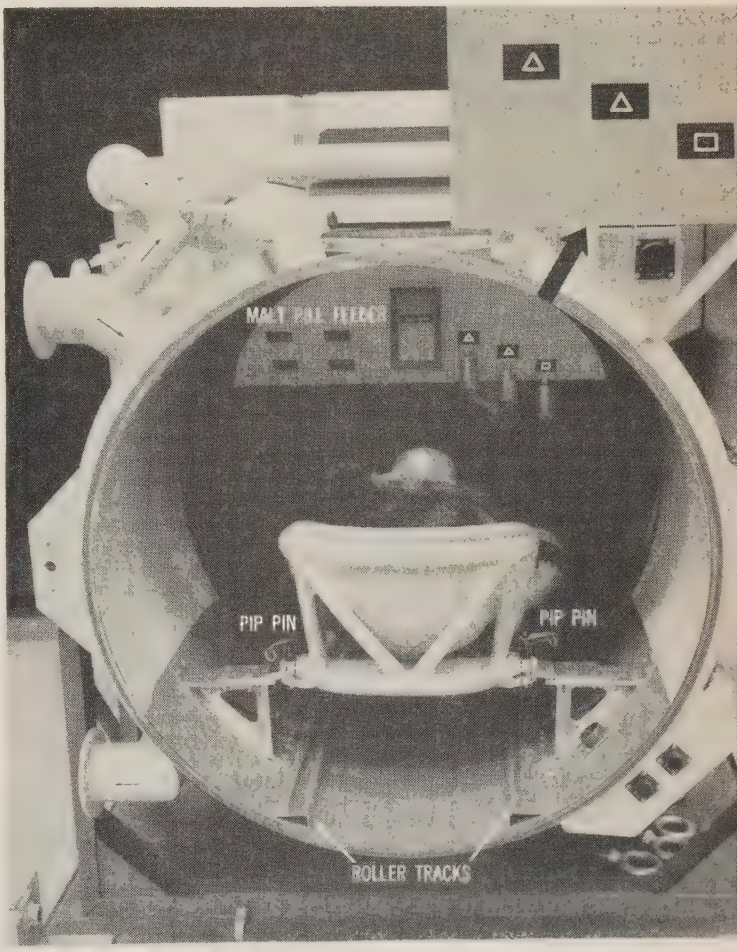
WHAT HAPPENS to a large animal in long-time orbital flight? In its "advanced biomedical capsule" (ABC) program, Lockheed Missiles & Space Corp. is trying to answer this question—in hopes, of course, of learning more about the problems of manned space flight.

The ABC program was started early this year and followed studies involving Lockheed Discoverer life capsules in which first mice and then a six-pound rhesus monkey were sent into orbit. This time Lockheed wants to try out an animal closer in size to man under more complex conditions. It decided to go from six pounds to fifty—the weight of a young chimpanzee roughly equivalent in age to a 3-4 year-old child. (A larger chimp is out because the brutes become mean as they grow older and very hard to handle. Since they are 5-7 times as strong as a man, pound for pound, adult chimps seem safe from the perils of space flight, unless any volunteer.)

The ABC chimp will be quite busy in orbit. The rhesus monkey had just one job: when he saw a red light, he

IN BRIEF

There is no substitute for the living "guinea pig" when it comes to studying the biological effects of space flight. One of the most important astronautic "guinea pigs" will be a 50-lb chimpanzee to be orbited and recovered in a Lockheed capsule. This report describes the chimp's life cell, the overall capsule, and the setup by which the animal will simulate manual pilot control operations. In addition, the capsule's environmental control system—based on the Mercury system—is reviewed in detail.



END VIEW of Lockheed capsule with chimp in the flight position. His major task is to push a handle to turn off the odd symbol of three shown on the right-hand side of the instrument panel.

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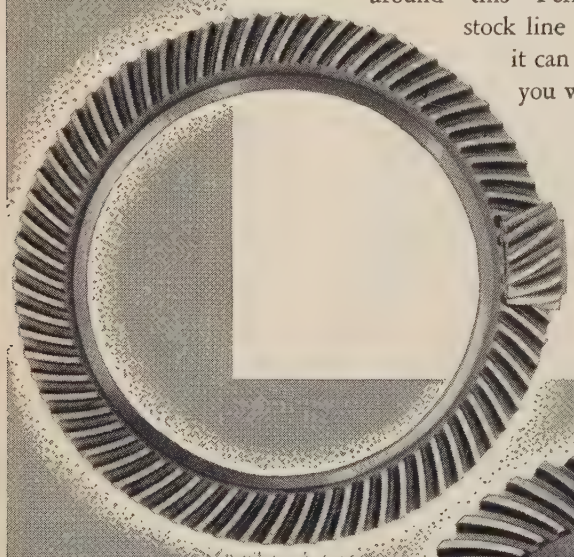
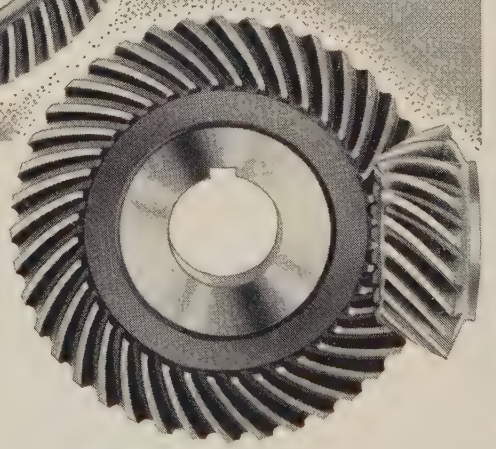
Now for the first time Perkins offers a complete line of stock spiral bevel gears with precision quality to help you get maximum savings in tooling expense and gear cost. When you're planning for spiral bevel gears, design your requirements around this Perkins stock line . . . it can pay you well.

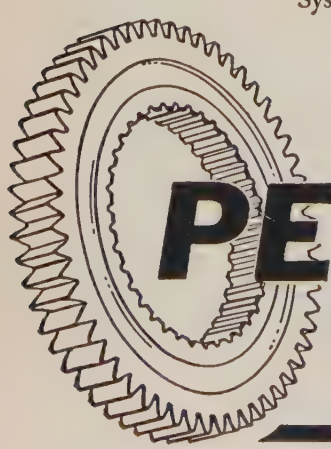




Perkins stock spiral bevel gears have soft bores and may be reworked to a maximum diameter. The gears are matched in pairs and lapped together after hardening for smooth running. In many cases these gears are available in left and right hand drives. This new line of stock gears includes the most commonly used ratios and sizes proportioned according to the Gleason Spiral Bevel Gear System.

AVAILABLE ON REQUEST:

This new folder includes all standard specifications of Perkins complete line of stock spiral bevel gears. Write for folder No. 7H.



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CAPSULE . . .

Table I: Thermal and Atmospheric Control System Requirements

Nominal atmosphere	pure oxygen
Atmospheric pressure	258 ±26 mm Hg
O_2 partial pressure	241 ±33 mm Hg
CO_2 partial pressure	0-2.6 mm Hg
Temperature (dry bulb)	80 ±5 deg F
Relative humidity	50 ±10 per cent
Trace contaminants	below human tolerance
Ventilation rate	30-50 fpm
Animal's O_2 consumption rate	0.015-0.072 pph
Leakage	0-0.012 pph
O_2 supply rate	0.015-0.084 pph
CO_2 production rate	0.017-0.079 pph
Respiratory quotient (CO_2/O_2 by volume)	0.80
Water vapor production rate (animal and CO_2 absorber)	0.052-0.315 pph
Animal's sensible heat load	46-141 btu/hr
Animal's latent heat load	47-295 btu/hr
Equipment heat load*	361-592 btu/hr
Internal heat load	454-1028 btu/hr
External heat load	−225 to 220 btu/hr
Net heat load	229-1248 btu/hr

*Includes electric power and heat generated in water and CO_2 sorbers.

was supposed to turn it off. The chimp has nine jobs.

The most important of these jobs requires him to act when he sees three symbols projected onto three small screens on the right-hand side of his instrument panel. Two of the symbols are identical. The chimp must notice the third odd one and push a handle to turn it off. This resets the projection mechanism to flash a different set of symbols onto the screens. If the chimp has pushed the correct handle, he gets a goody—a malt pill comes down to his mouth from a feeder in the center of the panel.

The chimp also must operate some simple devices on the left side of his panel—when a light flashes on there, a switch must be pushed to turn it off.

To the layman, all this might seem a lot to ask of a chimp, but doctors at Holloman AFB, N.M., who are working with Lockheed point out that it's as easy for a primate as playing the piano is for a child. Only one type of operation is involved, and that one is easily taught. In fact, the ABC chimp will scarcely be extended—there's a chimp at Holloman who can do 7000 operations in seven minutes and make only nine mistakes.

Animal triggers the telemetry system

A TV tube and a still-camera lens are located in front of the chimp's face. This system flips on every few minutes and data is stored for transmission both in real-time and

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Now available is a low cost, assemble-it-yourself fallout shelter that provides vital protection against nuclear radiation. It's an all-steel panel structure that can easily be erected in any ordinary basement. Compact, the unit accommodates 6 adults but covers a floor area of only 9' x 12'. Versatile, it can be used as a storm shelter, photo dark room, game room, or office. Developed over a period of three years in cooperation with nuclear physicists, industrial design firms and university consultants, the unit bears the seal of acceptance of the Office of Civil Defense. Produced by Heintz Division, Kelsey-Hayes Company, 102 E. Olney Ave., Philadelphia. Pa., the shelter is available through various retail outlets and local building supply dealers.

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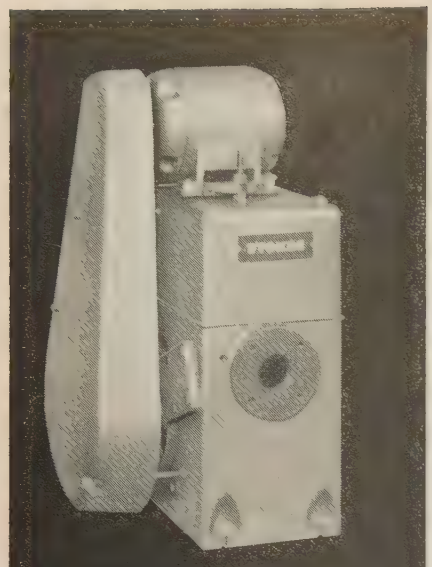

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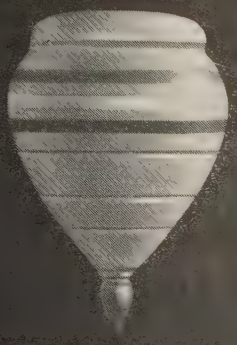

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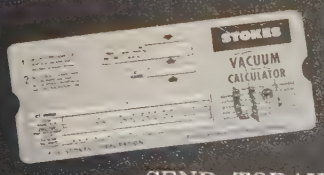

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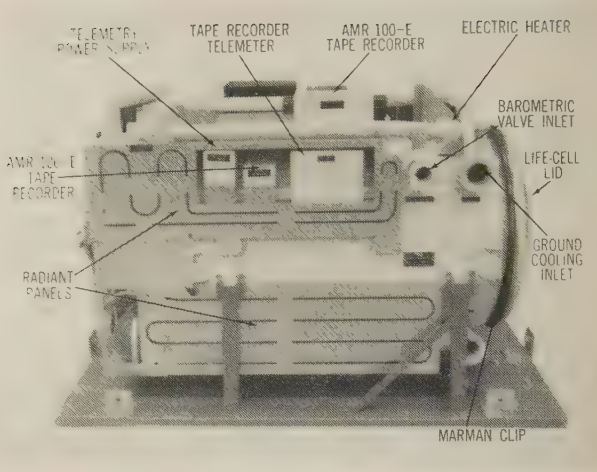


LEFT SIDE of the capsule carries radiant panels and the inlet snorkel. The life cell lid is in the sealed position.

single-frame form. Blood-pressure, electro - cardiograph, respiration, and other biological data are also collected. Every time the capsule comes over a ground station, a red light turns on in it, the chimp hits a switch, and an RF telemetry signal is sent out.

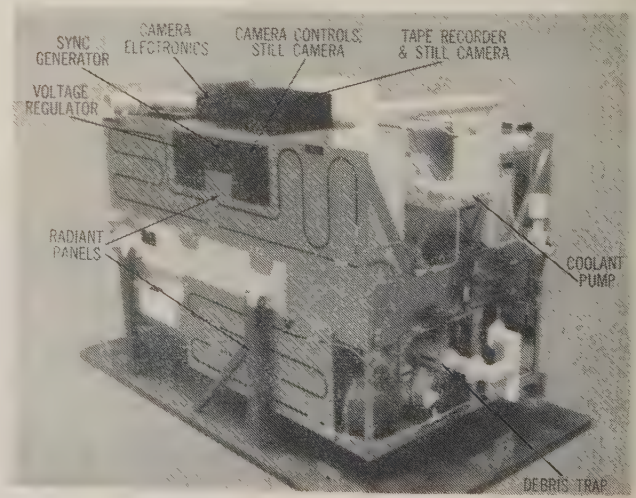
The ABC life cell is about 30 in. in diameter and 50 in. long. It is mounted inside a recoverable capsule that is about 3-4 ft wide and six feet long. At first, the Lockheed engineers had great trouble getting either a live chimp or a dummy in and out of the capsule —the job took over an hour. Then they redesigned their system so that the chimp's couch is held down only by two quick-release PIP pins. When the pins are removed, the couch slides out on small Teflon wheels. The lid that seals the top of the life cell is fastened down in a matter of seconds with a Marman clip.

According to the system design requirements, the chimp must be able to stay in the capsule for up to 74 hours—about 62 hours completely sealed off from the external environment and 12 hours with the system open to the atmosphere.

A nominal atmospheric pressure of five psia (258 mm Hg) was chosen to provide an oxygen partial pressure roughly midway between the limits of hypoxia and toxicity (*Table I*).

Certain data on chimps was lacking

Heat dissipation studies of human beings at 80 deg F dry bulb and moderate humidities show latent-to-total heat ratios ranging from 0.46 for persons seated and at rest to 0.70 for persons working at a rate requiring a heat generation of twice the basal metabolism. In the absence of corresponding specific

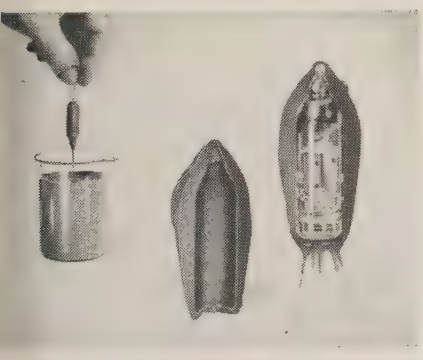


ONE OF TWO oxygen reservoirs is visible (at bottom) in this right-hand view of the capsule as well as the lines (also on the bottom) to and from the radiant panels.

General Electric Silicone Rubber finds dozens of uses in missile systems. How many more will prove vital?

General Electric silicone rubber has the "thermal toughness" to stand up under the searing heat of rocket blast-off or possible atomic attack. Add very good electrical properties and excellent resistance to aging, weathering, moisture, flame, ozone and corona and you can easily see why silicone rubber is now being used in virtually every U.S. missile and space vehicle.

Since both space technology and silicone rubber are relatively new, General Electric believes there are many more areas not yet explored where silicone rubbers can help keep a missile functionally reliable and combat-ready. To help designers in their evaluation work, we list here the principal properties and applications of G-E silicone rubber.



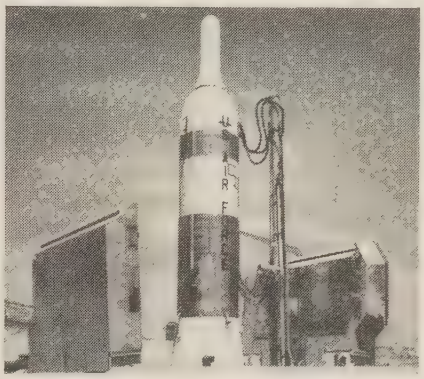
RTV LIQUID SILICONE RUBBER — One of the most versatile materials developed in recent years, RTV is a liquid rubber that cures at room temperatures. Like all silicone rubber, it remains flexible over a wide temperature range and is virtually ageless. Since it comes in a wide range of viscosities, it can be poured, sprayed, dipped, painted or applied with a pressure gun or spatula. It bonds tightly to metal when a primer is used. When not primed, you can readily remove RTV and then reapply more. You can impregnate tightly wound coils with RTV or form sections several inches thick.

You can control cure time from two minutes to 24 hours. These are RTV's typical properties:

Viscosity	from 120 poises (very pourable) to 12,000 poises (paste)
Specific Gravity	1.2 to 1.5
Solids Content	100%
Shrinkage	0.2%
Heat Resistance	from —90°F to 600°F, and as thermal insulation, in 5500°F flame for minutes
Ozone Resistance	Comparable to Mica
Electrical Properties	See last table

Applications—RTV is used as a high temperature structural sealant in missiles, satellites and space vehicles. It is used to pot and encapsulate electronic components and assemblies for electrical and heat insulation and for protecting delicate components from physical damage. It is commonly used as an impregnating insulation in transformer coils, to pot and hold cable in raceways and to pot cable breakouts. You can make flexible molds with RTV and hence make accurate, duplicate castings from originals.

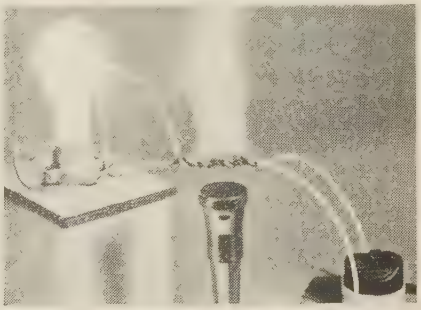
RTV is an excellent thermal barrier and as such is applied on and around missile nozzles. Tests show RTV's resistance to flame temperatures as high as 5500°F for several minutes. RTV also functions as a flexible ablative material and is used around probe holes, along raceways, and between stages and structural joints on the missile skin.



HEAT CURED SILICONE RUBBER PARTS —Silicone rubber gaskets, port seals, O-rings, shock mounts and other mechanical parts are not only used on missiles but have wide application in ground support equipment. For instance, missile silo doors use silicone rubber seals that will stand up to outside weathering, ozone and abuse for years and which will also resist the heat of missile launching and nuclear attack. Silicone rubber also resists brief exposure to cryogenic materials.

Silicone rubber has long-lasting temperature resistance from —150°F to 600°F, with excellent electrical, weathering, ozone, corona, radiation and nonaging properties at these temperatures. High tensile strength and low compression set are also within its range of desirable properties:

Tensile Strength, psi	800—1500
Elongation, %	100—600
Hardness Durometer (Shore A)	25—80
Compression Set, %	10—80
Tear Resistance lb/in	40—200
Radiation Resistance	1×10^8 roentgens
Electrical Properties	See table below



WIRE AND CABLE INSULATION — The long term reliability of silicone rubber when operating in high ambient temperatures and when current over-loads cause the conductor to approach 500°F is an important feature of silicone insulation. In an 1800°F flame, specially constructed silicone rubber insulated cables will continue to insulate for hours, forming a non-conductive ash that gives off no toxic fumes. And short term reliability is obtained even when silicone rubber is exposed momentarily to a direct flame of 5500°F.

Because of this excellent heat resistance, more current can be carried than in conventional cable (or smaller cable can be used). Other features: best compression set of all elastomers at temperature extremes, so that silicone rubber wire and cable does not deform under clamps; high ozone, corona, radiation and weather resistance, low moisture absorption, flexibility down to —100°C. These are the typical properties:

Volume Resistivity	10^{15}—10^{16}
Dielectric Strength, volts/mil	600—650
Dielectric Constant, 60 cps	3.0
Power Factor	.0010—.0050
Radiation Resistance	1×10^8 roentgens
Physical properties	Similar to table above.

Applications—Wiring harness made of silicone rubber insulation is often found throughout missiles. Cable offers added reliability for use in various places throughout the launch complex below ground from power plant to silos. All combat vessels built for the U.S. Navy during the last ten years, including fleet ballistic missile submarines and the new nuclear-powered cruiser and aircraft carrier, have silicone rubber insulated cable installations in all fixed wireways. In every case, silicone rubber is chosen because it is virtually non-aging, stands up to intense heat better than any other flexible insulating material, and continues to operate even when subjected to fire.

●

There are many more places where G-E silicone rubbers' inherent properties can be vital in missiles, satellites and space vehicles. For further data, call your nearest G-E sales office or write Section I1233, **Silicone Products Department, General Electric Company, Waterford, New York.**

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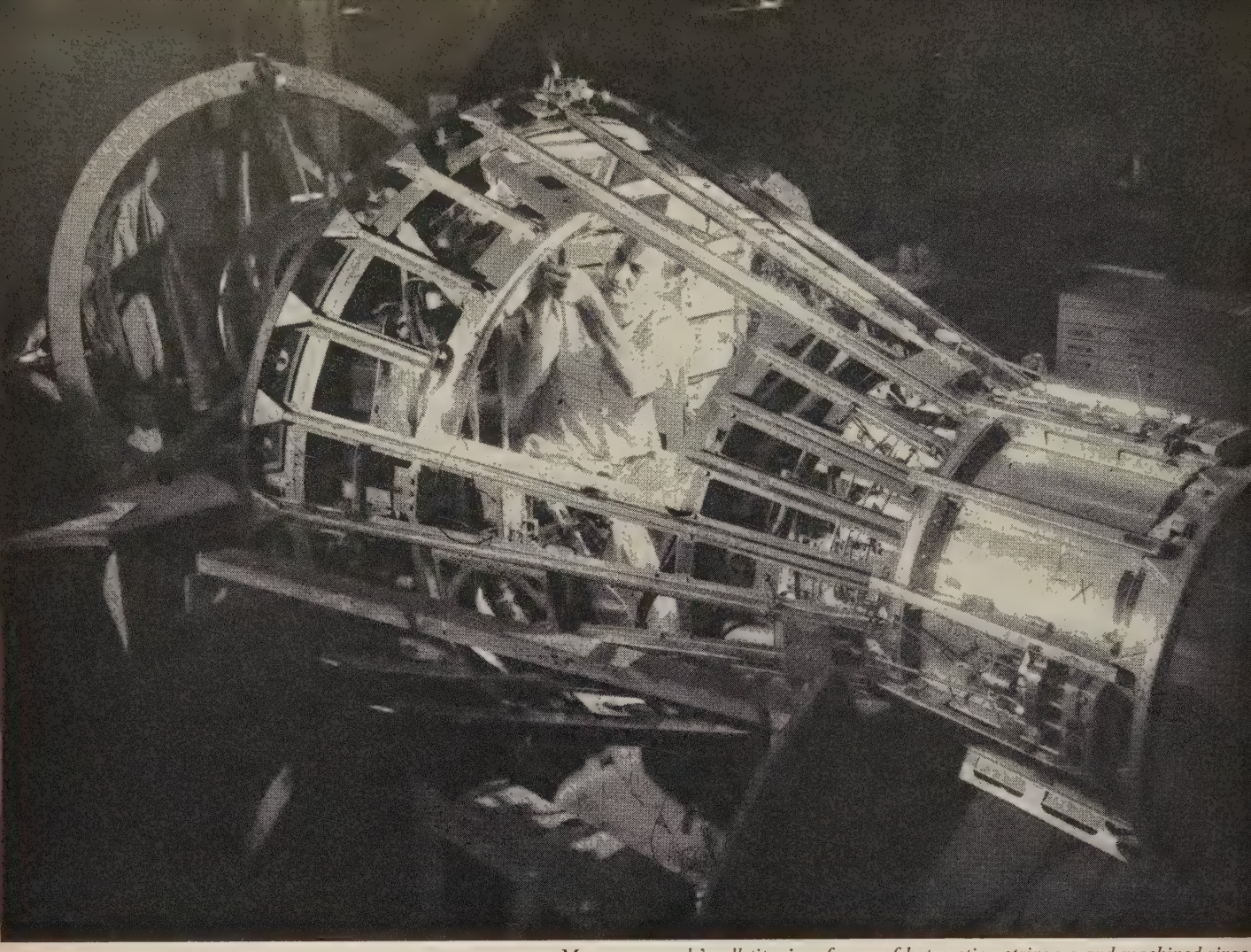

Mercury capsule's all-titanium frame of hat-section stringers and machined rings.

45,000 inches of welding

Titanium construction clinches record of reliability with Mercury capsule!

Mercury's astronaut, and all that was at stake with him, rode out the big shot safely in a titanium structure. Chosen for its light weight, its strength and rigidity at high temperatures, its ease of fabrication, titanium has passed another milestone in its growing history of reliability.

Project Mercury's pressurized capsule, its antenna and parachute housings and the adapter section mating it to the booster are basically titanium structures. They consist of a titanium inner skin attached to a framework of titanium stringers and rings. Beryllium and Rene 41 heat shielding "shingles" are fastened to the outside of the capsule.

The use of titanium has saved "considerable" weight over other metals of similar strength and endurance in the all-critical weight battle in the Mercury capsule and adapter section where ounces were fought for.

This report has been prepared by Titanium Metals Corporation of America in the belief that performance of titanium in the space capsule may provide information of use to you in design and construction of weight-critical airframe structures, whether they be in VTOL or STOL aircraft, or vehicles to operate in space.

Rigidity and strength at high temperatures . . . and 20 G's! Shaving off pounds was not enough for Mercury's designers. One of the big factors in the selection of titanium, which is as strong as most steels, yet weighs 44% less, is its ability to retain its strength and rigidity at high temperatures.

During the launch phase, the all-titanium adapter section reaches 600F. The titanium stringers in the capsule reach 600F during re-entry; the inner skin reaches 200F. Here titanium construction proves its high performance and reliability. Mercury capsule is designed to withstand 20 G's.

Titanium construction inherently rigid. Titanium lends itself to an actually stiffer construction even though its modulus is somewhat lower than steel's. The answer is a greater cross-section made possible by the less dense titanium. Moreover the metal will retain its stiffness over a wide range of temperatures.

Added stiffness and efficiency can be gained by "rigidizing" or beading. Mercury inner skin, which is also the cabin inner wall, consists of two layers of 0.010" commercially pure titanium, welded together to form a single "sandwich" structure. The inner layer is flat-rolled. The outer layer has been stiffened with corrugations approximately 3 inches in length and ½-inch wide. The result is a 0.020" titanium section that is equal in rigidity to an 0.050" section . . . 150% increase in efficiency.

45,000 inches of reliable welds per capsule. Project Mercury capsule, in addition to its high G loadings and temperature requirements, is pressurized to maintain its cargo of human life. Welds *must* be reliable.

According to McDonnell Aircraft, St. Louis, Mo., developers and manufacturers of the capsule, there are 24,500 inches of seam and butt weld and 20,500 inches of spot weld in each capsule . . . 45,000 inches of welding. The performance has been repeated in 20 production capsules.

Here indeed is a better focus on the reality of titanium welding!

All fusion and seam and spot welding was done "open air." Fusion welds were inert-gas shielded, tungsten-arc, using trailing and backup shields. Welds are as strong or stronger than parent metal, McDonnell reports.

Spot and seam welding was accomplished on standard production equipment, with techniques similar to those used on the stainless steels.

TMCA: your information source. If your missile or aircraft problems revolve around requirements for a rigid, high strength structure at temperatures from *minus* 433 to plus 1000F . . . with high corrosion resistance, including immunity to atmospheric attack, titanium may easily be your best answer. The reliability on which the makers of the Mercury capsule placed their faith can work for you.

We suggest you get in touch with the nearest Titanium Metals Corporation of America sales office or write directly to our Technical Service Department for information on titanium application . . . fabrication . . . competent fabricators. Why not write today . . .

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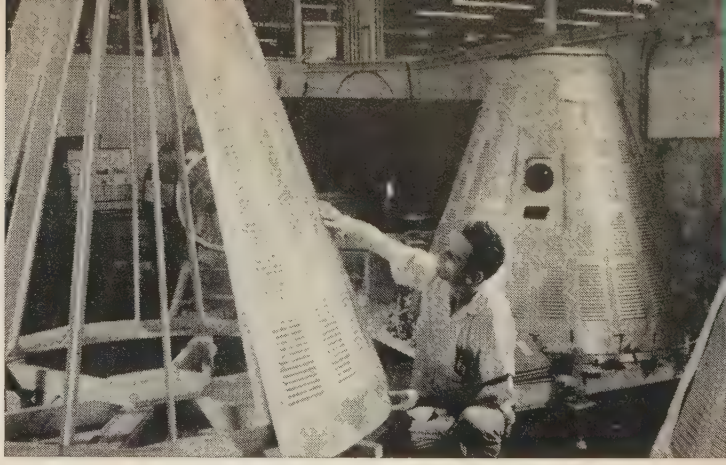
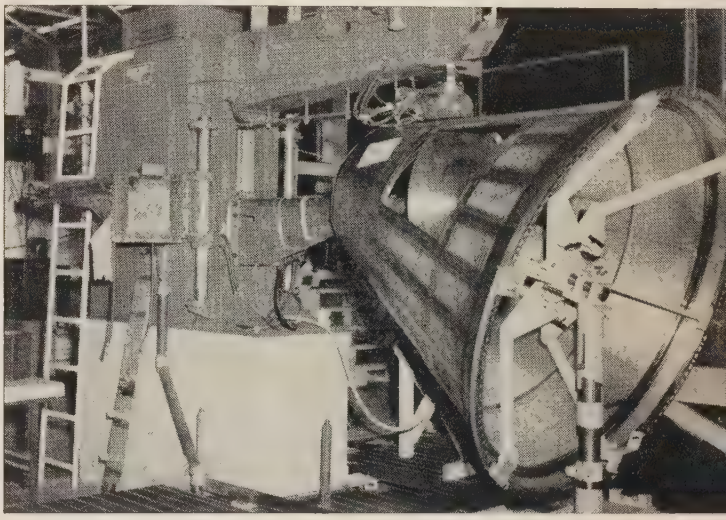
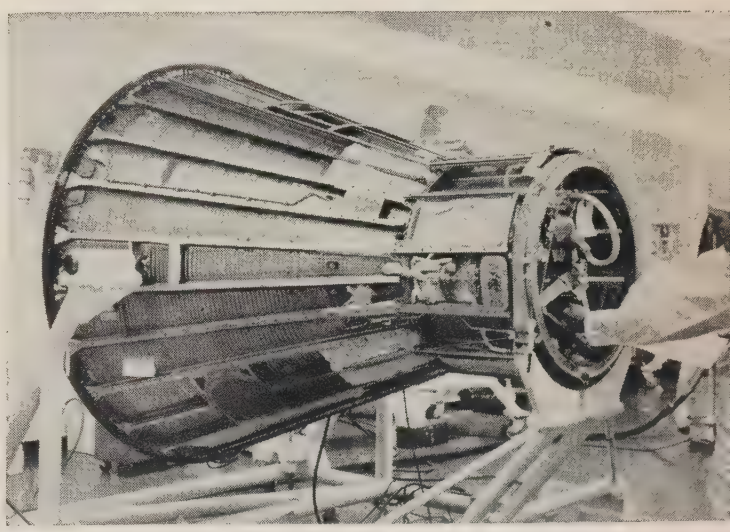


Titanium inner skin consists of two truncated cones 6½' high by 6½' at base, welded together. Cones are formed from trapezoidal sections, butt-welded together. One cone consists of 0.010" beaded titanium, for added stiffness; the other cone of flat-rolled 0.010" titanium. After butt-welding, each cone is individually pressure tested.



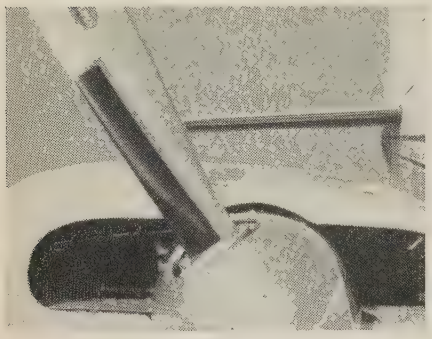
Cones are joined by seam-welding, the beaded cone on the outside, following spot-welding for position. Approximately 24,500" of seam weld are used in each capsule. A circumferential pass is made between each corrugation and a vertical pass adjacent to the corrugations. Joined cones are also proof-tested.



Basic titanium capsule structure consists of welded, two-layered cones which are spot welded to the titanium frame. The housing and adapter sections are not pressurized and consequently the skins are riveted to the frame in these areas.

Ideas you can use from

B.F.Goodrich



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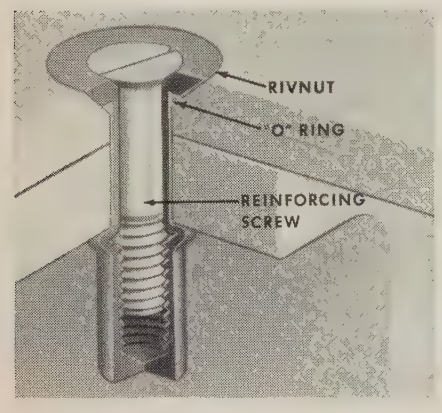

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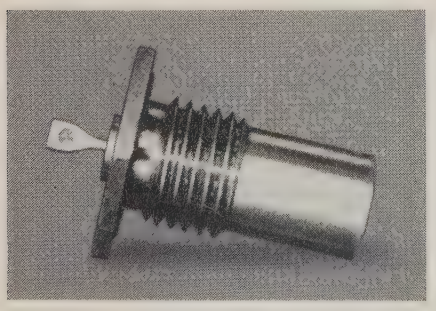

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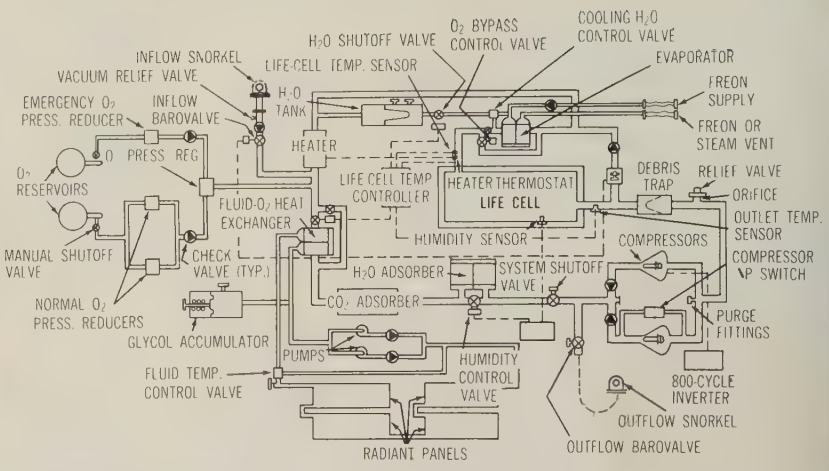
CAPSULE . . .



ENVIRONMENTAL capsule control system developed by AiResearch.

data for chimpanzees, Lockheed based its design on a latent-to-total heat ratio of 0.5 for the resting animal and 0.68 for the animal at its maximum level of activity. A relative humidity of 50 per cent, a gas velocity of about 30 fpm, and a thermal emittance of 0.5 for the life cell walls were chosen directly on the basis of data on chimpanzee behavior.

Average oxygen supply rate is 0.048 pph

The oxygen requirements were based on a daily regime of three hours of maximum activity, 15 hours at the basal rate, and six hours of sleep. The resultant heat generation of 146 btu/hr works out to an average oxygen consumption of 0.024 pph. Adding a 50 per cent safety allowance plus 0.012 pph for leakage gives a design average rate of oxygen supply of 0.048 lb/hr. For the minimum flight, oxygen must be supplied for about 14 hours before launch and 48 hours in orbit, so a total of three pounds of oxygen will be needed. During parachute descent and ocean recovery, no oxygen will be needed, for the cabin will be open to the atmosphere.

Lockheed studied several oxygen

Table II: Comparison of Oxygen Supply Methods

	Pro	Con
Gaseous	simple, no storage losses, no development needed	large volume, high storage pressure
Liquid cryogenic	low volume & storage pressure	losses during storage, zero-delivery & venting problems
Supercritical cryogenic	moderate storage pressure & volume, simple delivery & venting system	losses during storage, tank heating system required, development required
Potassium superoxide	no storage losses, performs multiple functions (O_2 supply, CO_2, H_2O & odor removal, pressure control)	multiple functions complicate control system, possible explosion hazard
Sodium chlorate candles	low volume, no storage losses	ignition system required, oxygen evolution uncontrolled after ignition

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STRATOFLEX PRODUCTS — PRESSURE AND PERFORMANCE RATED FOR ALL AIRCRAFT AND MISSILES

Shown above are a few of the Stratoflex hose assemblies most often specified for aircraft and missile fluid line applications. Each has been manufactured to the most rigid specifications and carefully inspected and tested to assure the highest standard of quality and performance. Available in a wide range of pressures, sizes and types for fluid applications, Stratoflex complete hose assemblies and hose and fittings allow the engineer exceptional freedom in equipment design. For hose and fittings that perform with complete reliability, regardless of your fluid line requirements, specify Stratoflex. For complete information, write for Stratoflex Aircraft and Missile Catalog today.

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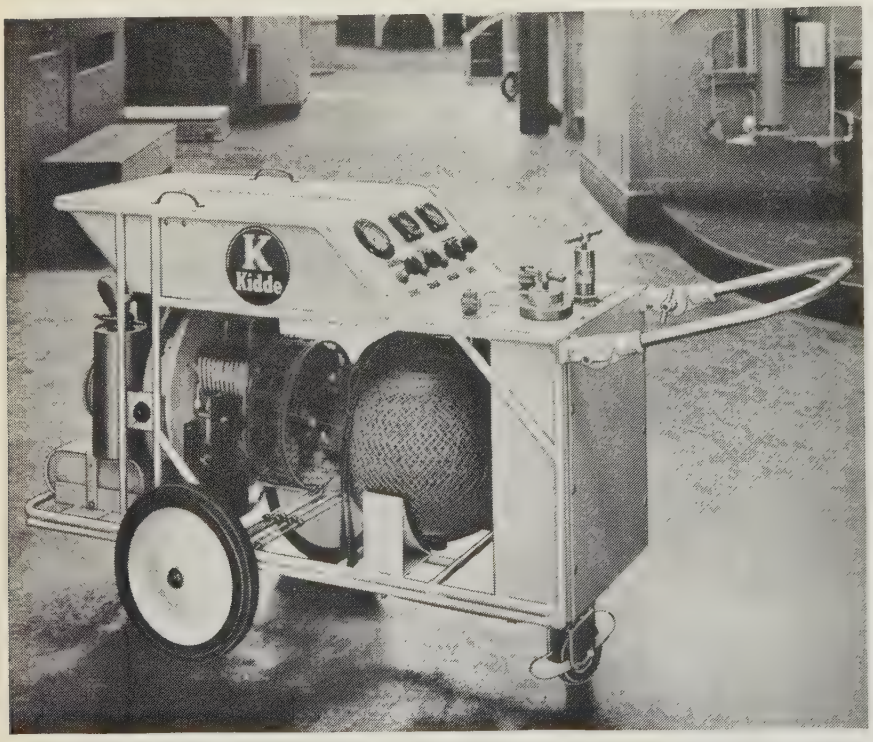
New Kidde 5000 psi pneumatic system features mobility, precision regulation!



From the laboratories of Walter Kidde & Company, Inc., comes this mobile pneumatic system which delivers 4 cfm of clean, dry air at pressures up to 5000 psi. Completely portable and easy to maneuver, the system features two highly accurate regulators: one for pressure ranges of 0-200 psi; the other for pressures up to 5000 psi. All controls and gauges have been placed at the optimum level for accessibility and ease of handling. Light in weight, the system measures 22″ by 49″ by 32″, and is available powered with either electric or hydraulic motors or gasoline engine.

Used for aircraft and missile ground-support equipment and for laboratory applications, systems of this type can supply high and low-pressure air in ambient temperatures varying from —40 degrees to +120 degrees F. For more information, write Kidde today.

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supply methods (*Table II*), as well as controlled leakage, expendable and regenerable-sorbent, and freeze-out systems for carbon dioxide removal and condensation-separation and expendable-sorbent systems for water removal. Its final design uses high pressure gas for oxygen supply, lithium hydroxide for CO_2 removal, and a non-regenerable absorbent system with a 13X molecular sieve for water removal. Reliability and availability of qualified hardware were the decisive criteria here, even though they involved a small weight penalty.

Radiant panels are used for thermal control

Evaporative water and radiant panels are used for thermal control during flight. For ground operations, freon is supplied to the water evaporator system. The radiant-panel system was chosen because of its value for extended missions and increased heat loads, when the weight and volume of water would become excessive.

The environmental system, developed by Garrett's AiResearch Manufacturing Division, is based largely on the Garrett system for the Mercury capsule. The primary system provides a relatively slow flow for moisture, CO_2 and trace contaminant removal as well as for orbital temperature control. The secondary system provides a higher flow rate for boost and re-entry cooling in addition to the required life-cell gas velocity.

In the primary system, a centrifugal compressor discharges into the molecular-sieve water adsorber. Oxygen is bypassed around the adsorber as required to maintain the required relative humidity in the life cell. It then passes through a lithium hydroxide unit, which also contains activated carbon and a dust filter.

The flow then enters the heat exchanger used for orbital cooling. Two pumps in parallel pump the transport fluid through the radiant panels. Excess heat is radiated into space through the recovery capsule's walls. The oxygen flow then goes through the heater into the secondary circulation duct. Oxygen is drawn from the life cell by a fan into the evaporator inlet. This oxygen mixes with return gas from the primary system and the combined flow passes through the evaporator and into the life cell.

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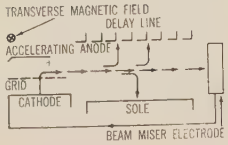
aerospace electronics

High-resolution AN/APS-94 side-looking surveillance radar gets once-over from Motorola engineer. The cigar-shaped unit, here installed on a Grumman AO-1BF Mohawk, is a "synthetic" array with a beamwidth a fraction of a physical array's with the same element spacing.

ELECTRONICS

"Miser" from Raytheon The microwave "miser" developed by its Spencer Labs is being hailed by Raytheon as a major breakthrough in the design of crossed-field microwave oscillators and amplifiers. It involves a new type of depressed-collector circuit that makes better use of the microwave beam than do present M-type tubes. A collector electrode gathers a portion of the spent beam at cathode potential and returns it to the cathode. The miser raises the power output for a given power input or alternatively lowers the power input for a given power output.



Circuit efficiencies have been proved out on S-band tubes at Spencer Labs. Tubes using the beam miser need no external mechanical changes nor additional electric input connectors. They directly replace standard tubes in the same sockets, says Raytheon.

New Solid-State Devices The combination of piezoelectricity and semiconductance in certain crystals may lead to a new class of solid-state electronic devices. Bell Telephone Labs scientists have amplified ultrasonic waves by introducing them directly into cadmium sulfide crystals. Amplification is brought about by interaction of the sound waves with electrons drifting in the crystal in much the same way as electromagnetic waves are boosted in a traveling-wave tube.

BTL's scientists report 18-db gains for a 15-mc ultrasonic wave traveling through a seven-millimeter-long CdS crystal and a 38-db gain for a 45-mc wave. A DC field is applied in the direction of wave propagation. The degree of amplification depends on the applied voltage and the conductivity of the material. As CdS is photoconductive, too, the conductivity of the material—and so the amplification factor—can be controlled by shining a light on the crystal.

Cheaper Thermoelectric Generators General Instrument announced a process for factory production of reliable thermoelectric generators at 1-20 per cent of the cost of present experimental models. GI hopes to produce generators selling for as little as $10 per watt of output power. The price tags for current developmental models varies from $50 to $1000 per watt, says the company.

Key element in the process is "Generalock," a new semi-metallic material invented by GI scientists. It has enabled the company to bond lead telluride to ohmic contacts with a very low junction resistance and high mechanical integrity.

Generalock can be made commercially in powder, strip, and disk form, GI told SPACE/AERONAUTICS. It melts and flows freely at a temperature that lies below the melting point of the thermoelectric materials themselves but far enough above the temperature of the generator's heat supply so that the bond and its electric properties are not affected. The Generalock material is applied at the junction points of the thermoelectric elements at temperatures above "red heat" in an enclosed, controlled atmosphere.

GI intends to make both Generalock and its manufacturing process available under license. Its president, Moses Shapiro, foresees a $100 million market for thermoelectric devices by '65.

Bigger Lasers A high-power CW laser has been worked out in theory by members of the research staff at Nuclear Research Associates, Long Island City, N.Y. and is being built in hardware model form. It uses a new pump that "is neither an optical type nor does it use either electromagnetic or electrostatic separation of atomic states in the active material," according to the company, which expects to develop a laser that will be many orders of magnitude greater than present cw types. The pump scheme, it says, is not confined to any particular wavelength or material.

Glass lasers were invented by American Optical's Research Department. The use of glass, says AO, makes it possible to build larger lasers whose output is easier to control. It also cuts cost, according to the company, and makes possible specially shaped lasers—e.g., a laser in the form of a glass fiber.

The glass lasers developed by AO use trivalent neodymium as the active ion. Their output is in the infrared at about 1.06 microns.

AO, which has set up a subsidiary, Laser, Inc., devoted entirely to laser development, is one of some 50 groups working on lasers in this country. The market for lasers and related coherent-light devices will expand to $0.5-1.5 million a year by '70-'74, according to government and industry marketing specialists.

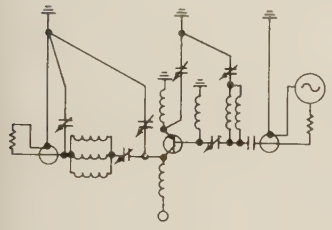
USAF O.K.'s TDDL After a lengthy, large-scale test program at AFSC's Electronic Systems Division, time-division data link finally got USAF's stamp of approval. Links were installed in F-101B, F-102A, F-105, and F-106 planes for the program, and tests were also run with Bomarc missiles out of Eglin AFB, Fla.

Built by RCA, the data links are being used in air-defense aircraft as part of the Sage system, which can now be flown manually in accordance with ground commands visually displayed in the cockpit. The commands can also be routed directly to the aircraft's autopilots for automatic flight under Sage control. Previously frequency-division data links had been used, which had proved erratic in the dense RF interference environment of the continental U.S.

Navy Also Has TDDL AN/USC-2, a time-division data link system developed for the Navy by Bell Telephone Labs has a similar purpose. It can provide two-way communications to as many as 100 aircraft over a single radio channel. Each aircraft can be given a complete set of instructions of its own once every few seconds and can reply with a status-type message derived

INTELLIGENCE

from information generated aboard the aircraft. Data rate from ground to air is about 10,000 words per minute. As in USAF's TDDL, transmission is via UHF.



Transistor Range Extended A novel circuit developed by a Motorola engineer greatly extends the useful frequency range of transistors and increases the stage gain of VHF and UHF units by more than 20 db in some instances. These gains are brought about by a compensation network that neutralizes the inherent inductance of the emitter circuit.

In one case, the frequency output of a normally rated 200-mc transistor is extended to nearly 500 mc. (see Schematic). Part values can be adapted to the parameters of the transistor.

Commercial Gear for USAF Jet Commercial Arcing-spec electronics will be used to the greatest possible extent in the C-141 jet cargo transport, being built for USAF by Lockheed. The commercial gear should lower costs considerably without any compromise in quality. The transport is being designed to meet several kinds of military airlift needs and therefore, according to USAF, must meet the military's requirements for specific wartime missions as well as the requirements of civil air freight operators.

The C-141 is being designed for trans-oceanic hops at 400 knots cruising speed. Its first flight is set for '63, and it is expected to be in the operational inventory by mid-'65. A USAF representative will report on the status of the C-141 electronics at the Airlines Electronics Engineering Committee General Meeting this month in Washington, D.C.

President Asks FAA to Carry Out Project Beacon ATC Recommendations

Tomorrow's interim air traffic control system will be built around ground radar, altitude-coded transponder beacons, and general purpose computers, if the recommendations of the Project Beacon report are carried out. The report, made by a special AA-appointed task force that studied the "Safe and Efficient Utilization of Air Space," was submitted by FAA Administrator N. E. Halaby to the White House early last month.

Halaby recommended that the "concepts, conclusions and recommendations of the Task Force . . . be approved as guidance to the FAA and to the other Departments and Agencies concerned for whatever implementing action appears appropriate." Within a week, the President answered by requesting that FAA "begin at once to carry out those recommendations of the report which you believe will move the airways program forward rapidly and efficiently."

The next move now is up to a systems design team being formed by FAA under the leadership of Al Brown, assistant FAA R&D director. This team is to recommend how the conclusions of the Beacon report can be put into effect.

Something New in ATC As pointed out by Halaby, the Beacon report does three things:

- It analyzes the present methods of air traffic control.
- It recommends a number of improvements that can be made in the near future.
- It represents an advanced concept for an ATC system to meet future needs but using facilities of the present air defense and ATC systems.

The report is unique in the annals of ATC by virtue of its clarity, logical reasoning, and simplicity. It might be accused of being unimaginative, but in this day of exotic and super-sophisticated systems, it seems rather a sound engineering approach based on current hardware or reasonable extensions of it.

Beacon's Recommendations Many of the Beacon recommendations should have a profound effect on certain segments of the aerospace electronics industry. Among these are:

- All aircraft above 12,500 lb gross weight should be required to carry altitude-reporting beacon transponders for use both en route and in terminal areas. (Transponder beacons are now required in all airline jets but so far have only identification but no altitude encoding. They are being used for identification and radar reinforcement.)
- When a cheap (about $500), short-range (50-mile) altitude beacon becomes available, it should be required in all aircraft landing at controlled airports within designated congested terminal areas.
- General-purpose computers should be used in both the en route and terminal area portions of the ground ATC systems to process flight plans, issue clearances, make conflict probes, generate display information, establish landing sequences, and perform other routine ATC tasks.
- Only the radar part of Sage should be integrated into the ATC system.
- Special navigation facilities should be provided in the very near future for efficient copter operation in terminal areas in instrument weather.
- Special navigation facilities also should be provided to permit closer paralleling of airways over a few very high density routes for fixed-wing aircraft.
- Continued work on all-weather landing systems is essential—primarily to improve the reliability of instrument landings at present minimums but also for eventual operation under zero-zero conditions.
- No satisfactory collision avoidance or proximity warning scheme appears feasible in the near future. The present schemes are either marginal or economically not feasible. Work in this area, however, should be continued.
- No automatic ground-to-air communications is needed for the recommended ATC system. There appears

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BENDIX NOZZLES FOR THRUST VECTOR CONTROL

Thrust vector controls to steer space vehicles with needle-threading accuracy are the subject of extensive research and development now being carried on at Bendix.

One technique being explored for Polaris and other missiles and spacecraft is secondary injection. The use of liquid or gas to deflect the exhaust jet provides a control system of great simplicity and reliability, while maintaining pinpoint accuracy. Another Bendix control development—part of the Minuteman program—is movable nozzles. A pressure-tight, flexible seal permits nozzle swiveling to provide thrust vector changes, allowing course and/or attitude corrections. Qualified contractors: write us at South Bend, Indiana, for more details.

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to be no chance in the reasonably near future that equipment will be developed that is low enough in cost and weight to make the universal use of a data link feasible. An automatic air-to-ground data conceivably might be an important future adjunct of the ATC system, but this prospect is too remote to warrant development work on the basis of today's technology.

- Radio-direction-finding strobes would be a useful tool for the ATC system.

Price Tag: $500 Million The Beacon task force estimated that the ATC system it proposes would cost the government a total of $500 million and could be put into operation within five years. Most of the money would go for electronic equipment. In addition, the airlines, and companies and private persons owning planes, would spend several million dollars on airborne beacons.

Basically the Beacon ATC system calls for the control of aircraft on the basis of three-dimensional (altitude, range, azimuth), ground-derived position. The emphasis would shift from flight strip postings to radar displays. Other basic provisions are:

- the separation of fast and slow traffic in certain instances;
- possible control of all traffic above 24,000 ft MSL in mountainous parts of the U.S. and above 14,500 MSL in all other parts:
- a new flight category—CVR (*c*ontrolled *v*isual flight *r*ules)—to enable the non-instrument-rated pilot to use the positively controlled areas under VFR;
- the designation of separate climb and descent channels for various aircraft types in congested areas.

What about Sage? The rejection of Sage was a severe blow to the many factions within USAF that hoped to give the air defense system a stronger lease on life by expanding its role to include ATC. The Beacon task force claims that, in the long run, modifying Sage to take on the ATC assignment would cost the government far more than if only the radar elements of Sage are used and the present civil system is modified. It also predicts that operationally there would be conflicts of control priority and differences in performance needs (e.g., on radar displays) for air defense and ATC.

Many Washington observers believe, however, that the last word has not yet been said on the use of the full Sage system for ATC. They can already point to a straw in the wind—the last sentence in President Kennedy's letter of concurrence to Halaby on the Beacon report: ". . . you will consult with the Secretary of Defense and those responsible for the air defense system, as well as my Scientific Advisor, Dr. [Jerome] Wiesner, so that the optimum application of all the resources of the Government in the safe and economical use of the airspace may be assured."

The combination of Sage and ATC had been studied as Project Satin (*S*age *a*ir *t*raffic *in*tegration) by Mitre under contract to FAA and with USAF support. Mitre set up an experimental en-route system between the New York City and Boston, Mass., air route traffic control centers to investigate the possibility of integrating the en-route ATC functions with the air defense functions of Sage and to explore the application of advanced data processing techniques to ATC. It concluded that integration with Sage could lead to a better and more efficient ATC system and is economically feasible.

Work on Special Computers The Beacon task force's recommendation in favor of general-purpose computers will not kill off research on advanced special-purpose data processing systems for future ATC control, claims FAA, which says the general-purpose machines are intended basically for the interim system ('65-'75). As a result of the Beacon report, Univac general-purpose computers will probably be installed in the busiest ATC traffic control centers.

A case in point is the new Boston center (at Nashua, N.H.), which was to get two Librascope special-purpose computers but now will get a Univac. The Librascope computers, FAA speculates, might go into Atlanta, Ga., and Jacksonville, Fla., centers. Three other Librascope computers are being programed at FAA's NAFEC in Atlantic City, N.J., and will be kept there for experimentation.

Other units of the GPL-Librascope "data processing central" will be used in its ATC development program, says FAA.

Copter Navaids The Beacon task force said that the copter navigation experiments run last in New York City area with the Decca VLF hyperbolic system showed "reliable service with adequate accuracy" but also "some presentation problems." It noted that a system based on multiple DME measurement has also been studied and concluded that one-nm positional accuracies are easily obtained, half a mile is generally possible, and 0.2 nm is possible with specially located facilities.

Its report further mentioned that advances in the frequency stability of oscillators (e.g., through the use of atomic standards) bid fair to make possible distance measurement by one-way transmission of radio signals (on the basis of phase comparison and cycle counting). Steep-gradient aircraft (copters and V-STOLs) need a landing aid specially tailored to their flight characteristics, the task force also concluded.

All-Weather Landing The Beacon report added little that was new on all-weather landing systems. It reaffirmed that such a system would have to be highly reliable—as reliable, in fact, as satellite electronics.

We can't expect substantial reductions in landing minimums, at least not for large jets, until suitable flare transition and low-altitude guidance schemes are developed, the task force noted. The angular glide-slope coverage of the present ILS system is not wide enough, according to the Beacon report, for the variety of descent profiles best suited to high-performance aircraft.

Needles Still Lost According to Lincoln Labs, telemetered data from the Agena-B carrier vehicle show that the cylinder containing 350 million 0.7-in.-long passive reflector dipoles went into orbit at about 2000 miles altitude. A month after the October 21 launch, no radar contact has yet been made with the package, which is only six inches in diameter and 17 in. long. The dipoles are embedded in naphthalene, supposed to evaporate in space within a few days after release.

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Survey of electronic trends most significant to national defense was run by DOD's Office of Electronics. Forty-nine top technical people in government and industry were asked three questions:

- What are the most important electronic research areas?
- Which areas of electronics are most likely to produce significant changes in our military posture and when?
- What do you consider the most significant electronic or related research being done in your own organization?

The replies were published as OTS Document 171881, "Important Areas of Electronic Research" (dated January 1961) but released only recently. The most striking feature of the replies, DOD states, was the rather sharp division of electronic research into two major and several minor areas. The major ones are:

- science and technology relating to components, including research on materials, solid-state devices, microminiaturization, and reliability;
- systems research, covering communications and command control, computers and data processing, bioelectronics, adaptive systems, pattern recognition, and artificial intelligence.

The minor research areas were propagation; energy generation, storage, and conversion; antennas; low-noise amplifiers; and the radiation environment.

Overall the replies emphasized systems research. DOD's summary notes that the reliability of future electronic systems depends on today's component research and to a lesser extent on system research. It also states that the "frequency gap" is being reduced, that we are pushing toward new levels of power, and that new electronic devices have come into existence mainly through basic research in physics and mathematics.

Commenting on communications, the report says that "modern communications is distinguished from World War II communications primarily by the use of statistical communication theory, low noise-temperature receivers and antennas, and transistorization of data processing devices. Virtually every major advance in communications in the last 15 years can be placed in one of these three categories."

New career for aerospace electronics engineers is that of securities analyst. The high interest of the many investors in electronics has created a big demand for technical men with a good understanding of the facets and the jargon of aerospace electronics—who can evaluate the efforts, developments, and goals of new and old, large and small companies in the light of overall industry trends.

Wall Street and other financial centers have come to the conclusion that it is much easier to teach an engineer the rudiments of investment practice than to teach a financial man what he would have to know about electronics. Salaries run around $15,000. The employers are usually investment houses and are looking for broad, rather than specialized, technical experience.

Penetration Aids Section of Aeronutronic is working on super-secret decoys for USAF's ICBM program.

The presentation problem, long the Achilles' heel of the British Decca navigation system has been solved in Decca Navigator's latest model, which will be rolling off the production lines in mid-1962. The "new-look" Decca will include a half-ATR-size digital computer and a new display. The "Omnitrac" computer converts the hyperbolic position coordinates determined by the Decca receiver into rectilinear units. This makes it possible to use undistorted charts instead of the present hyperbolic presentations, which are not true analogs of conventional flight maps.

The new system undoubtedly will force FAA to take another long, hard look at the unsolved copter navigation aid problem. In a previous evaluation, FAA admitted it liked Decca's accuracy and reliability but not its display distortion. Of course, Decca in any case still must scale the "buy American" hurdle.

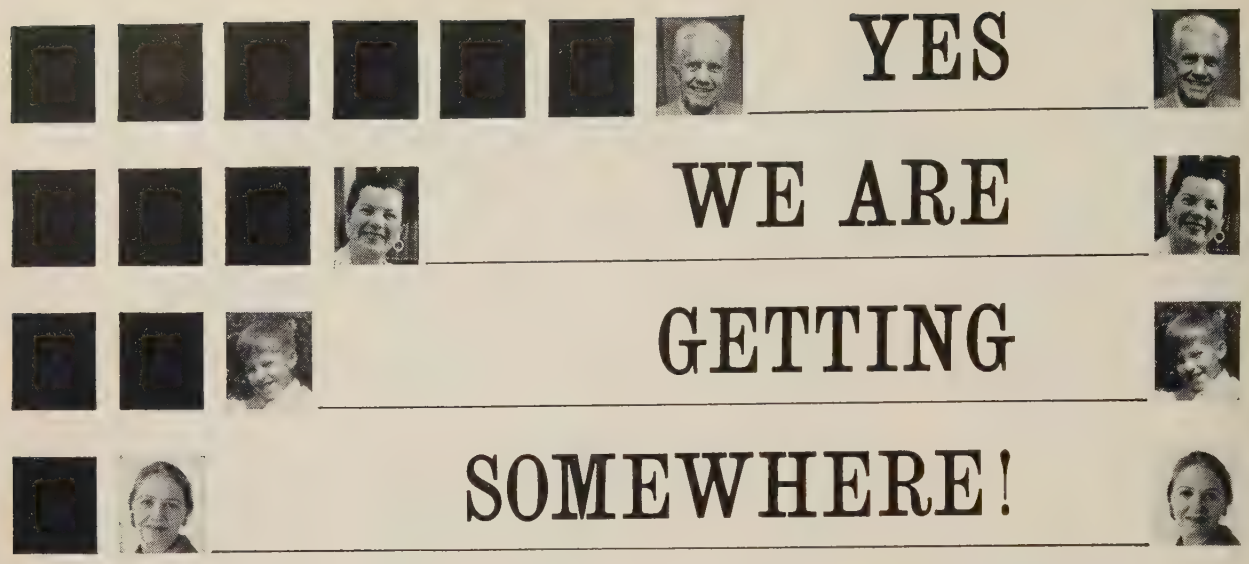
Interest in aerospace electronics is running high for the 1962 IRE International Convention, to be held in New York City in March. Largest number of papers submitted for the technical sessions are in the Aerospace and Navigational Electronics group. The convention will have a total of 54 technical sessions, sponsored by the 27 professional groups of IRE.

Lunar guidance in the 1965-70 period will be based on a five-unit, integrated subsystem, predicts Ralph C. Hawkes, Nortronic's chief of systems research:

- an astro-inertial platform with a two-star tracker,
- wide-and-narrow-angle optical earth and moon trackers,
- an integrating computer clock,
- a radio altimeter.

As reported in the *Northrop Technical Digest,* Hawkes claims that this system would satisfy the primary guidance requirements of the 12 phases of a lunar mission: earth launch, parking orbit, injection, midcourse, lunar approach, circumlunar passage, lunar orbit, lunar landing, lunar launch, return midcourse, earth approach, and re-entry. The system could be cut to four units with the development of an earth-moon tracker that can operate in both wide- and narrow-angle modes, Hawkes believes.

"Newtonian Navigation", a booklet written by Autonetics' J. M. Slater and published by the company, is a concise, easily understood treatise on inertial guidance stripped of involved math and instrumentation problems. It also has sections on inertial-optical combinations for terrestrial and space navigation.



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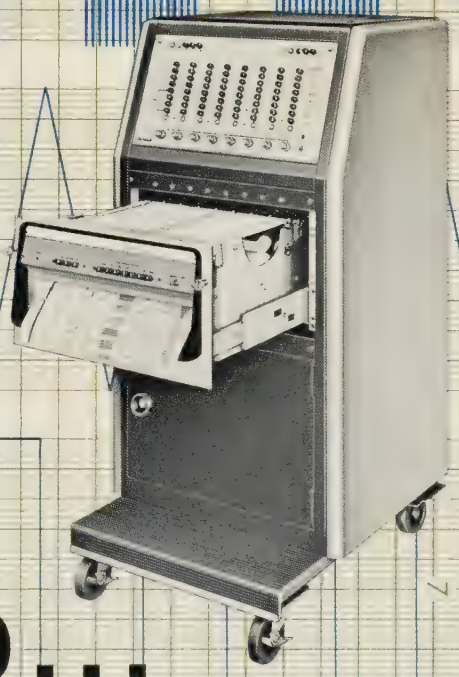

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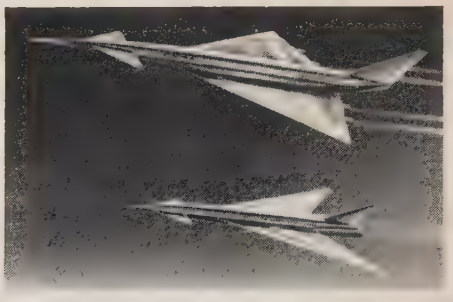
AERIAL MISSILE LAUNCHER. Photo shows Boeing B-52 missile bomber making in-flight launch of Hound Dog missile, which flies at supersonic speed toward target far ahead. In addition to missiles, versatile B-52s can carry regular bomb-bay load of gravity bombs. New B-52H, with turbofan engines and sophisticated electronics, is tailored for wide variety of Strategic Air Command mission requirements. Later, B-52H will carry hypersonic Skybolt ballistic missiles, a 1000-mile weapon under development.

Capability has many faces at Boeing

JET HYDROFOIL. Drawing shows jet-powered twin-hull test hydrofoil Boeing is designing and building for U.S. Navy. Hydrofoil will "fly" on under-water wings at 115 mph.

TWIN-TURBINE helicopter, Boeing-Vertol 107, seats 25 and will enter service soon with New York Airways. 107s have been ordered for service in Japan, Canada and Sweden. Military version is being built for U.S. Marine Corps.



SUPERSONIC JETLINERS. Boeing continues to invest substantial sums in supersonic jet transport research. Drawing shows two Boeing designs being studied. Supersonic jets would fly two to three times speed of sound, make flight from New York to London in under three hours.

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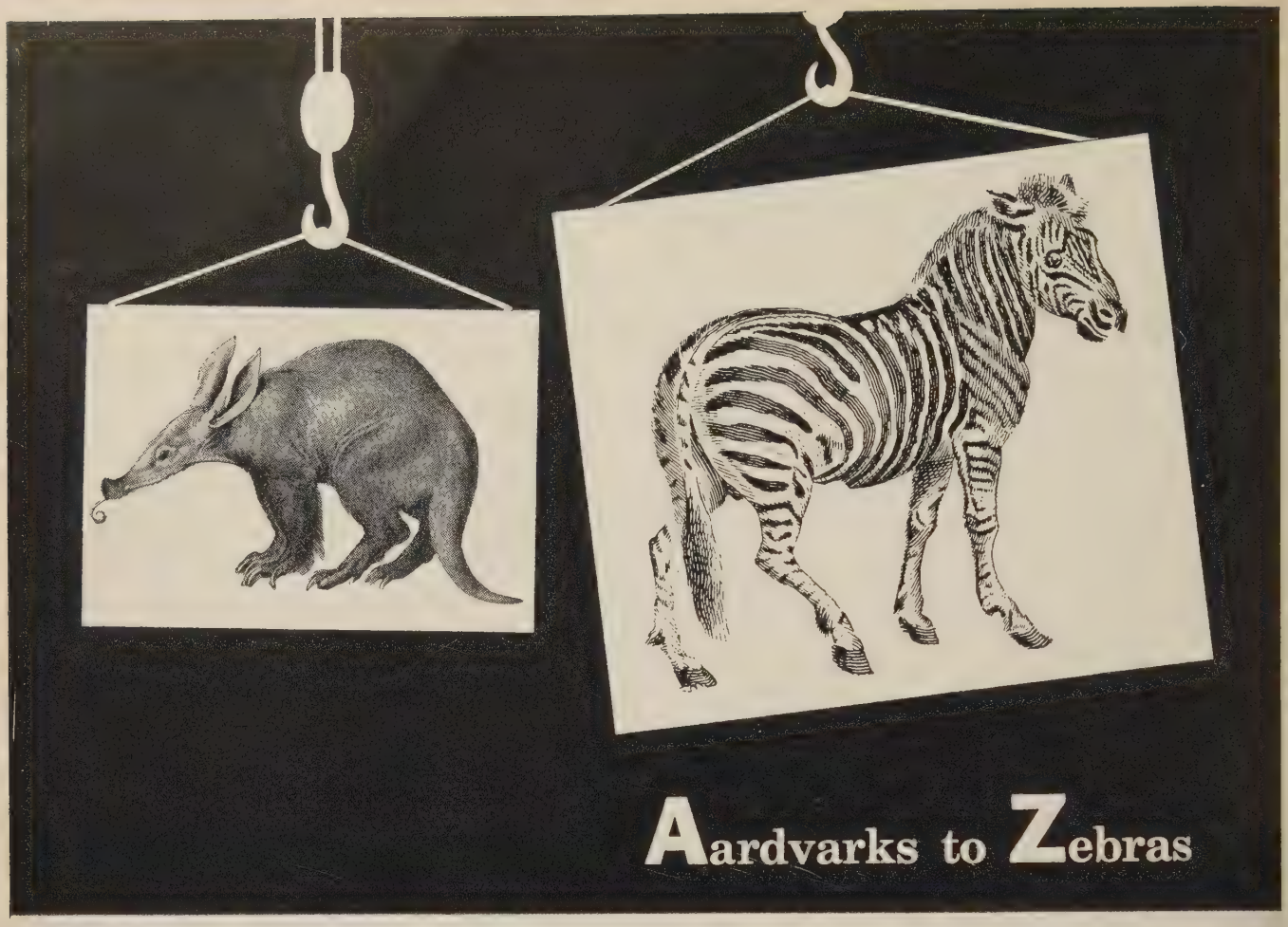

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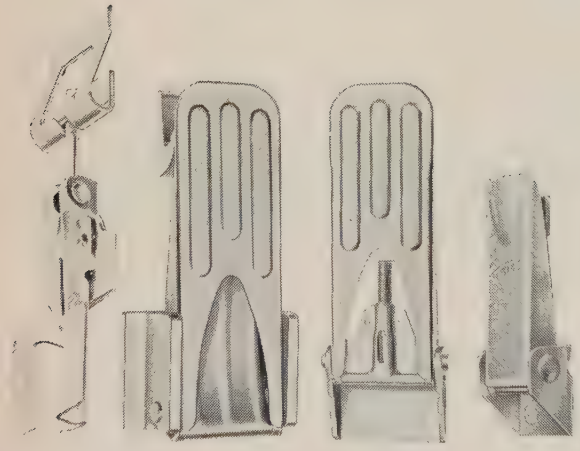

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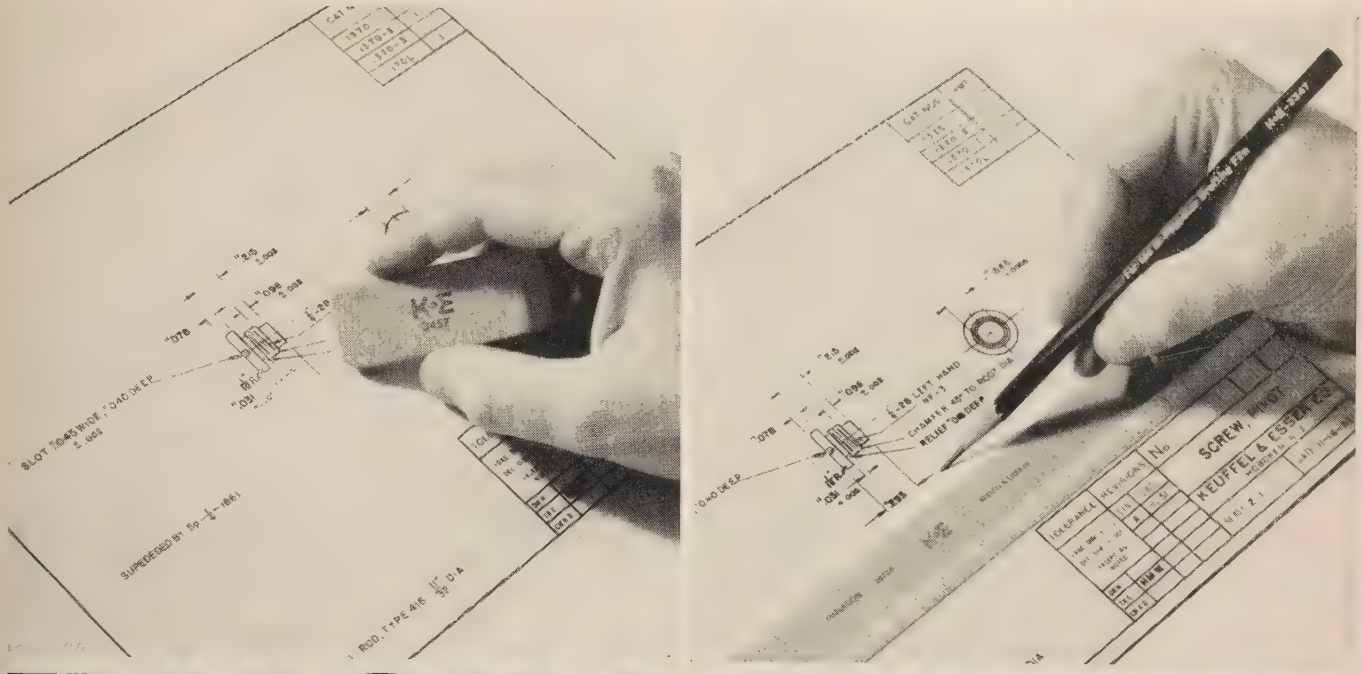

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Self-adaptive flight control

without test signals

SELF-ADAPTIVE CONTROL adjusts one or more system parameters in accordance with what is going on in the system itself, and in such a way as to meet a performance requirement. A conventional, programed gain-change flight control is adaptive only in an open-loop manner—the results of the change do not directly affect the signals that cause the change. The gain change in an altitude-Mach-programed flight control, for example, affects neither altitude nor Mach number, which are both outside the loop being controlled.

In a self-adaptive system, changes caused by the self-adaptive controller immediately affect the input to the controller—there is a closed loop, which is the most attractive feature of the self-adaptive control. The self-adaptive system adjusts itself by monitoring some system characteristic and not on the basis of prearranged programs based on observations external to the system.

* Light Military Electronics Dept., General Electric Co., 1 River Rd., Schenectady, N.Y.

Among the requirements of self-adaptive flight control are:

- The system should be non-tailoring.
- Transient response should be invariant.
- The steady-state response should have zero error.
- The system should be self-adaptive by variation of a single parameter.
- Test signals in the form of periodic steps, white noise, or limit cycles should not have to be used.

The "non-tailoring" characteristic eliminates the costly flight test programs needed to set up conventional air-data gain-changing programs. A properly designed self-adaptive system requires only the general limits of the vehicle's dynamics, which are readily available from the preliminary design data. Tailoring is needed for setting the control-actuator signal and power levels, but for these no flight-testing is necessary.

Invariant response is desirable since it simplifies the problem of integrating the various control loops. For

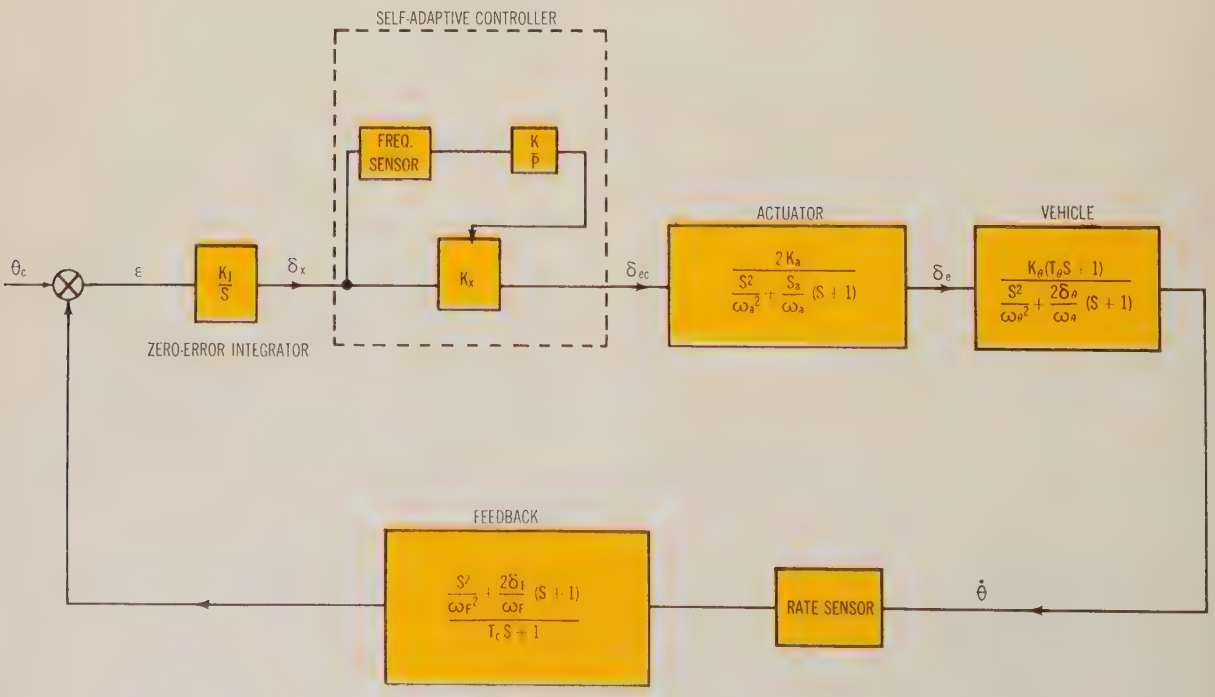


FIGURE 1: Basic self-adaptive flight control system.

by Richard G. Buscher, Development Engineer, Armament & Control Section,
Light Military Electronics Dept., General Electric Co.*

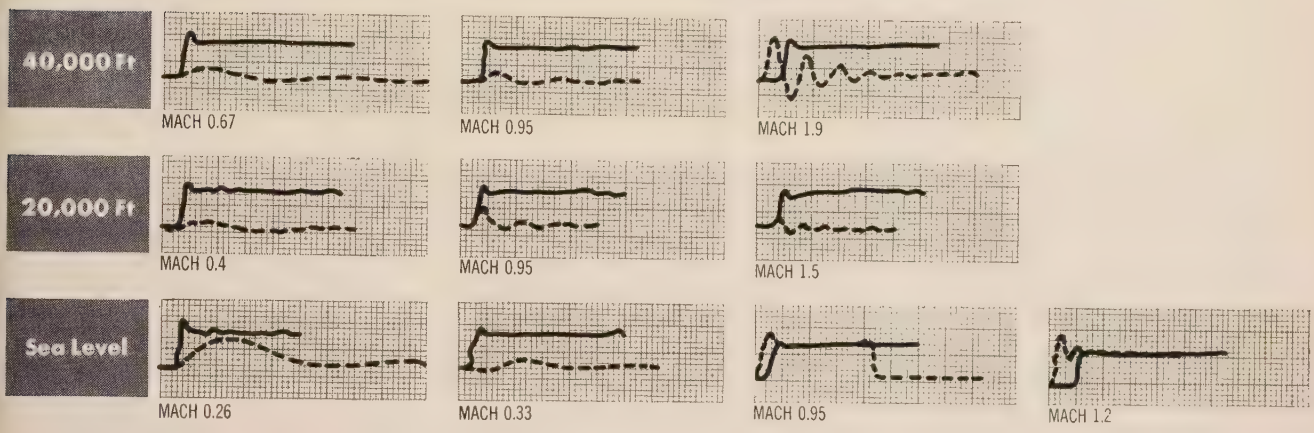


FIGURE 2: Typical closed-loop response vs time for self-adaptive system in typical high-performance aircraft. Aircraft step response (dashed curves) varies widely, but system step response (solid curves) is invariant.

piloted vehicles, an invariant response lets you specify the required dynamics (compatible with the pilot's capabilities) within narrow limits.

Zero-error steady-state response provides constant closed-loop gain, making it easier to integrate inner and outer control loops. It also eliminates "attitude drift" and provides automatic trim. Single-parameter variation is recommended because it simplifies the mechanization and because of the risk of interaction between multiple parameters.

Since some particular system response characteristic has to be continuously monitored in an adaptive system, it seems logical that this characteristic should be excited or present at all times. For this reason, several proposed self-adaptive controls use test signals in the form of steps, white noise, or limit cycles. These signals are undesirable, however, as increasing the wear and tear on actuators, the control power consumption and also as causes of pilot discomfort.

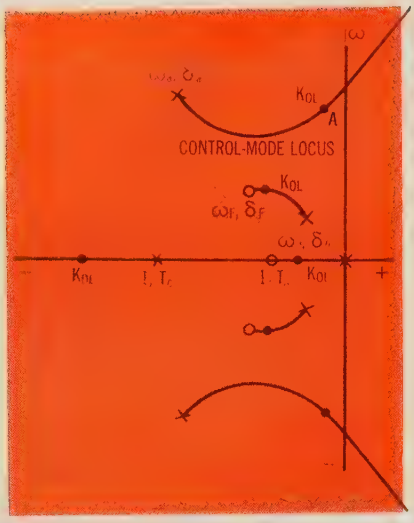
A better approach is to monitor a characteristic inherent in the system's normal transient response to commands and disturbances (e.g., gusts). When this is done, the vehicle cannot go from one flight condition to another without exciting the characteristic that provides the information needed by the self-adaptive controller. With no disturbance or command, the system is at rest.

Figure 1 shows a self-adaptive system that meets these requirements. In its operation, this system is based on

IN BRIEF

Self-adaptive flight control systems offer two important advantages over conventional, programed gain-change systems: They take less time and money to develop (since costly flight-test programs are eliminated) and they automatically and continuously adapt themselves to the requirements of the vehicle environment.

Those systems continuously monitor their own operation and provide essentially continuous gain change when needed. The particular configuration analyzed in this article uses no test signals (which would be undesirable) but instead monitors the system feedback response at a point at which the natural frequency of the system is predominant. Optimum system operation is maintained by changing the gain to keep this frequency constant for all disturbances and situations within the range of required control performance.



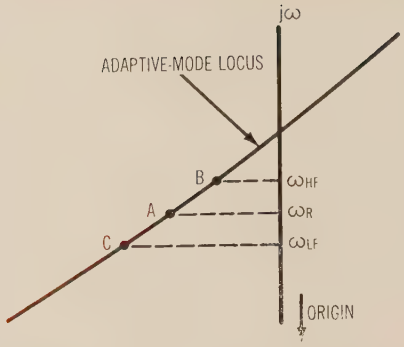


FIGURE 3: Root-locus plot of the system of Figure 1 and enlarged view of the area around point A.

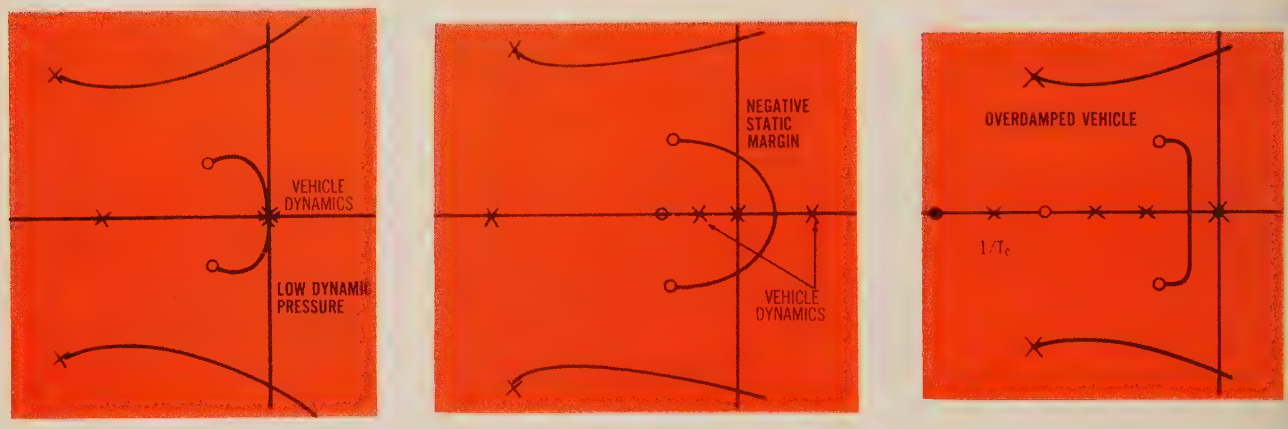


FIGURE 4: Root-locus plots of self-adaptive control systems for three types of aerospace vehicles.

the fact that, when the open-loop gain of a closed-loop system is very high, the closed-loop response is essentially the inverse of the feedback. For this system, the closed-loop response with high open-loop gain is essentially quadratic, at frequency ω_F and damping δ_F. The values of these two quantities are determined by the gains of the feedback quantities, which are set by the designer. Variations in the vehicle transfer function do not affect closed-loop operation, since the response is the inverse of the feedback.

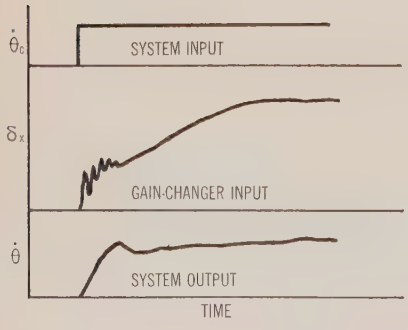


FIGURE 5: Self-adaptive system responses to a step input.

In any practical flight control system, there normally is a limit to the open-loop gain beyond which some system mode becomes unstable. The self-adaptive loop in the system of *Figure 1* prevents such instability. The monitored characteristic in this system is the mode of oscillation, or adaptive mode, that approaches instability with increasing loop gain.

Oscillation is always convergent

The controlled parameter is the open-loop gain (K_x), which is adjusted continuously to keep the adaptive mode in the region of 0.2 damping. The adaptive-mode oscillation is, therefore, convergent at all times. The low damping value provides the reason the vehicle cannot go from one condition to another without exciting the monitored characteristic. It also insures that any system transients cause this mode to appear in the loop oscillations.

The overall result is that the open-loop gain is always at its maximum allowable value for stable operation. The closed-loop response is virtually invariant, with ω_F and δ_F as the predominant frequency and damping (*Fig. 2*).

The root-local diagram for the system of *Figure 1* shows that, with proper design, the feedback zeros (ω_F, δ_F) can be placed so that the vehicle's poles (ω_θ, δ_θ) end in the zeros under infinite gain (*Fig. 3*).

When the gain is increased from very low values to the value indicated by K_{OL} in order to place the oscillation mode of actuator poles (ω_a, δ_a) near the imaginary axis, the system operates at maximum allowable gain. The other poles are then driven along their loci to the points marked by K_{OL}.

Point A on the adaptive-mode locus (where the gain is K_{OL}) now defines an operating point for the system. When the system's open-loop gain is adjusted to keep the closed-loop adaptive mode at point A, the system operates at maximum gain and the closed-loop poles on the ω_o, δ_o to ω_F, δ_F, locus remain close to ω_F, δ_F—even with large variations of ω_θ, δ_θ due to changes in flight conditions.

The short-period transfer function in *Figure 1* and the root locus of *Figure 3* both apply to a typical aircraft. *Figure 4* illustrates the case of a vehicle with low dynamic pressure, with the transfer function a pole at the origin. This situation occurs with hovering vehicles (ground-effect machines and VTOLs) during landing and take off and with re-entering spacecraft. As dynamic pressure builds up, the root-locus diagram takes the form shown in *Figure 3*. *Figure 4* also shows the locus plots for a vehicle with a negative static margin, with a stable and an unstable pole on the real axis, and for an overdamped vehicle, with the transfer-function plot giving a zero and two poles on the real axis. In all the examples shown in *Figure 4*, the vehicle poles are driven to the ω_F, δ_F zeroes and held there by variations in the open-loop gain.

Natural frequency also changes

The method of gain variation is important. The closed-loop oscillation (the damped natural frequency) of a quadratic pole is characterized by the imaginary component. As the gain varies and the adaptive-mode pole moves around point A in *Figure 3*, the damped natural frequency of this mode also changes. With excessive gain, the adaptive-mode pole moves along the locus to point B, where the damped natural frequency is ω_{HF}. A reduction in gain moves the pole to point C, where the natural frequency is ω_{LF}. Self-adaptive loop operation then becomes a monitoring of the damped natural frequency.

If the frequency varies from ω_R (at point A), the gain is increased or decreased to force the system frequency back to ω_R. Since the vehicle gain (K_o) produces loop-gain variations as a result of flight-condition changes, the absolute value of K_x varies, even though the closed-loop adaptive mode stays at Point A. This means that the gain-change rate is proportional to the frequency shift. K_x is held at the proper value by integrating these frequency-shift signals. To minimize the frequency error, the self-adaptive position mechanization includes a frequency sensor with an output proportional to the frequency error and an integrator that varies K_x by integrating the frequency-sensor output.

Oscillation detected at gain changer

The adaptive-mode oscillation is detected by the frequency sensor, at the input to the gain changer, because it is predominant at this point, as is shown by the step response of the system (*Fig. 5*). With bandpass filters and suitable means of frequency-sensing, the frequency shifts about ω_R are determined, and the gain is varied accordingly.

Too much gain would make the system unstable, but with a carefully chosen operating point and an optimized self-adaptive loop this should not happen. If instability appears nevertheless, the actuator acts as a safety device. Its rate-limiting action, caused by saturated control-valve flow, makes it impossible for a divergent oscillation to build up beyond a certain magnitude. As a result, the system response will degenerate into a limit-cycle operation. This undesired operating mode then will vanish again as the frequency sensor detects the error, reduces the gain, and recovers stable operation within a few cycles of limit-cycle behavior.

The feedback transfer function in *Figure 1* is a quadratic zero over a single-order pole, and in addition there is a zero-error integrator in the loop. The most obvious method of obtaining this feedback configuration is to

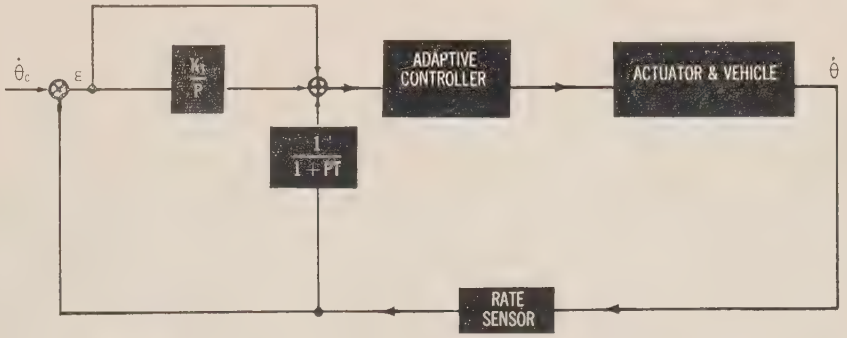


FIGURE 6: Simple type of self-adaptive feedback mechanization.

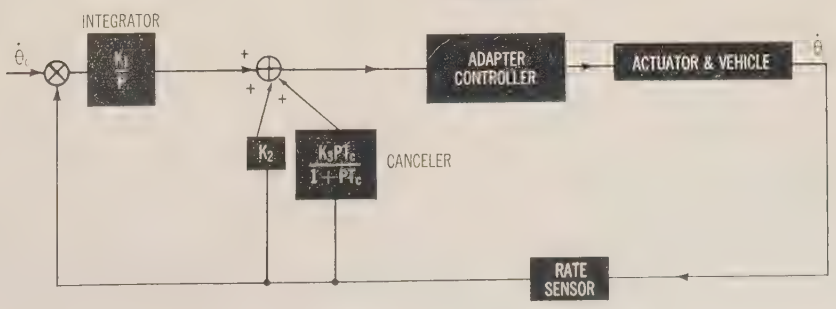


FIGURE 7: Improved type of self-adaptive feedback mechanization.

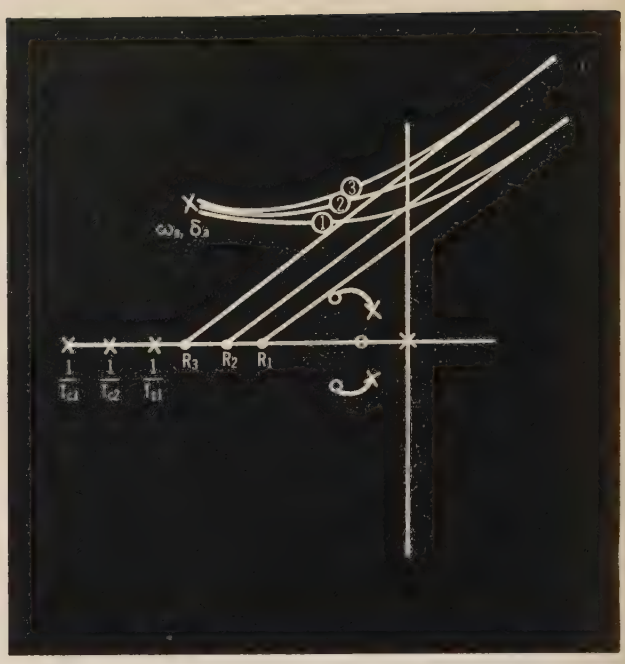


FIGURE 8: Envelope of typical dynamic vehicle response and variation of T_c with changing ω_a, δ_a loci. Locus 1 provides insufficient frequency shift per gain change; loci 2 and 3 represent successive improvements.

sense angular rate and its first and second derivatives (i.e., acceleration and jerk), and feed them back through the lag. While angular-acceleration sensing might be feasible, today's mechanisms for sensing angular-jerk are too noisy to be useful.

Figure 6 shows a more advantageous configuration—no angular-rate derivatives are needed, so there is no problem. However, to bypass the integrator and get the system error, an adder-amplifier is required.

Several methods of cancelling

The system of *Figure 7* has neither angular-rate derivatives nor an adder-amplifier. In this mechanization, ω_F and δ_F become a function of the gains K_1, K_2, and K_3 as well as the time constant (T_c). For canceling, or rate wash-out, a number of methods are being used in today's flight control systems, so that it looks as though available components might be used for this function. Two major requirements of the system of *Figure 8* must be met in positioning the feedback zeros and the canceler lag (T_c):

- The vehicle poles (ω_θ, δ_θ) must end in the feedback zeros (ω_F, δ_F) for the vehicle's operational envelope.
- The adaptive-mode locus must rise as it crosses the imaginary axis to provide a suitable relationship between imaginary frequency and open-loop gain.

Figure 8 plots a system application, showing the envelope of the vehicle-pole variations, the T_θ-variation, the actuator position, and a "first guess" for T_c. The proper position for ω_F and δ_F is found by trying the various extreme cases. Care must of course be taken that ω_a, δ_a does not end in ω_F, δ_F.

Next the location of T_c is modified in accordance with the fact that, for high gain, the asymptotes of the loci intersect the real axis at some point R. The frequency at this point is the sum of the real parts of the pole frequency minus the sum of the real parts of the zero frequency. By varying T_c, R is shifted so that the ω_a, δ_a locus crosses the $j\omega$ axis as desired.

Once the value of T_c is chosen, the location of ω_F, δ_F is rechecked. It should not have to be changed, for the higher-frequency loci can be varied somewhat without affecting the ω_θ, δ_θ to ω_F, δ_F locus.

The whole process is iterative and does not involve as many trial-and-error decisions as seem necessary at first glance. It can be programed on a digital computer or a root-locus plotter like the Esiac.

The variations of ω_θ, δ_θ cause some shifting of the adaptive-mode locus in the region of cross-over. This error—on the order of 1-2—is not enough to produce operating difficulties. Once the positions of ω_F, δ_F, and T_c have been determined, the feedback gains are found by simple algebraic solutions.

The self-adaptive system we have reviewed was originally simulated on computer and jig setups and later flight-tested in a Convair F-106. The theoretical assumptions have been verified in pitch and roll channel operation in subsonic, transonic, and supersonic flights at various altitudes and under various flight conditions. The tests proved that self-adaptive control of monitoring a system characteristic without the use of test signals is feasible.

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Fiber optics

in aerospace electronics

The manipulation of light rays used to be the exclusive province of classical optics. However, light is a form of electromagnetic radiation, and probably it was inevitable that electronics should become concerned with it. Actually, it has become concerned with a vengeance—not a surprise at a time in which the laser, for instance, is one of the most promising new electronic devices. It is because of the definite trend toward the generation and transmission of light for electronic purposes that the new field of fiber optics is of such importance to aerospace electronics.

Fiber-optical bundles of glass fibers, properly aligned and coated, offer an excellent method of channeling light or visual images from one point to another. Though a great deal of work is being done on fiber optics, so far little has appeared in print about it, especially not concerning the problems of fiber-optical devices in aerospace electronic applications.

PRINCIPLES OF FIBER OPTICS

by J. W. Hicks and P. Kiritsy, *Mosaic Fabrications, Inc.* *

FIBER-OPTICAL transmission of light is a waveguide phenomenon, but it can be explained nevertheless on the basis of geometric optics, or ray tracing. To begin with, a single glass fiber with parallel sides and ends is normally clad with a glass coating that has an index of refraction (N_2) lower than that of the glass fiber (N_1). Light intersecting the central axis of the fiber within a critical cone angle (θ_m) is internally reflected from the sides and passed down the fiber (*Fig. 1*) at the far end.

The maximum value of θ_m is given by:

$$N_o \sin \theta_m = \sqrt{N_1^2 - N_2^2} = NA,$$

where NA is the numerical aperture and N_o is the index of refraction of the surrounding medium (1, in the case of air).**

The amount of light striking the axis of the fiber is a direct function of the value of angle θ_m. $N_o \sin \theta_m$ consequently is also a measure of the light-gathering power and for this reason equal to the numerical aperture. For those used to photographic terms, the f-number is identical with the reciprocal of 2 NA. A low f-number indicates large light-gathering power. In the air, for which N_o is 1, NA cannot exceed 1. Therefore, the f-number theoretically can approach 0.5.

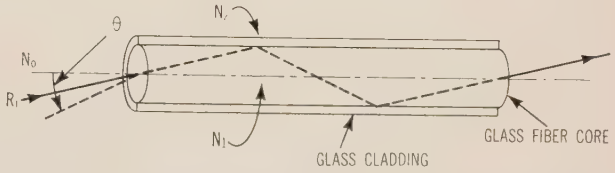


FIGURE 1: Ray of light enters a single glass fiber within the maximum angle (θ_m) for internal reflection and transmission. Rays striking near the end of the fiber at angles exceeding θ_m are reflected and scattered. N_0, N_1, and N_2 are the refractive indexes of the surrounding medium, the glass core, and the fiber cladding.

If a ray enters a single fiber at some angle θ smaller than θ_m, it should ideally emerge at this angle, too. Because the exit azimuthal angle varies rapidly with θ, fiber length and diameter, and other factors, the emerging ray fills the annulus of a cone of half-angle θ (*Fig. 2*). By changing the shape of the far end of the

* Mosaic Fabrications, 205 Chapin St., Southbridge, Mass.

** This relationship is exact only for ways intersecting the axis fiber. Furthermore, the effective numerical aperture, except for circular-cross-section fibers, is always less than the theoretical value of $\sqrt{N_1^2 - N_2^2}$, because either the resolving power or transmission drops sharply near the calculated value. Effective numerical apertures therefore are based on the requirements of operational optical systems.

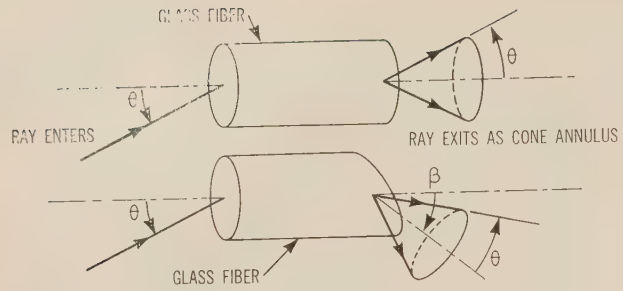


FIGURE 2: Ray entering the fiber at angle θ emerges as the annulus of a cone with half-angle θ (top). Different effects can be produced by changing the geometry of the fiber. A biased end cut, for instance, shifts the exit cone through angle β (bottom).

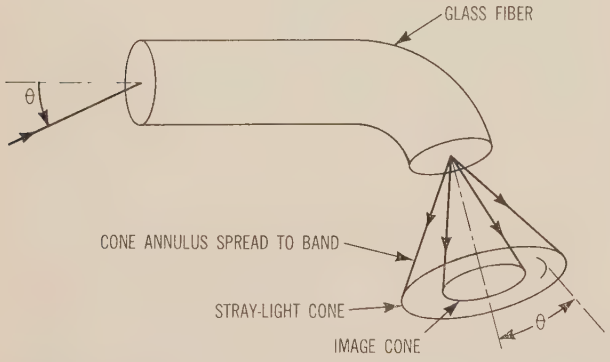


FIGURE 3: Bending of the fiber decollimates the exit annulus and increases the exit angle.

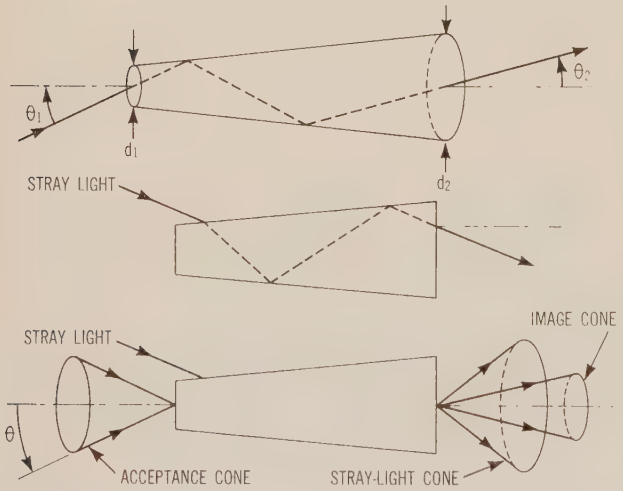


FIGURE 4: Entrance and exit angles of tapered fibers (top), trapping of stray light approaching from the side (center), and the effect of untrapped stray light from the side (bottom).

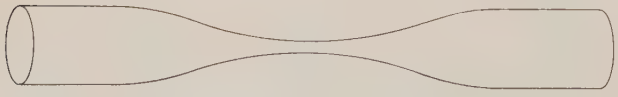


FIGURE 5: In the center-tapered aperture choke, the smallest diameter determines the acceptance angle.

fiber, the emerging ray can be manipulated. A biased end-cut produces the effects of a prism, shifting the exit annulus towards the tip of the cut.

Making a ray emerge at θ is made difficult by several practical problems, such as diffraction at the ends, minute grooves or channels in the fiber, surface roughness, and bending of the fiber. *Figure 3* shows how bending in particular decollimates, or opens up, the exit annulus and increases the exit angle over θ. The degree of this decollimation can be computed from a set of coefficients. It must be considered when light is passed into a fiber at unusually low numerical apertures, in which case an aperture transformer may have to be applied.

Light is decollimated at large end

Tapered fibers as well as straight ones can be used in fiber-optical devices (*Fig. 4*). In their case, the angle at which a ray exits differs from the angle at which it entered in accordance with:

$$d_1' \sin \theta_1' = d_2' \sin \theta_2.$$

The net effect is that light entering the small end becomes more collimated as the exit diameter increases. Light entering the large end, on the other hand, becomes decollimated, and if the entrance angle exceeds the maximum acceptance angle (θ_m), light spills out the side. For the same reason, light approaching the side is trapped—an effect exploited in one form of injection lighting. In some cases, the sides of tapered fibers are blackened to avoid stray light, although such light ideally lies outside the image cone.

Fibers tapered in the center provide "aperture chokes" and increase the depth of focus (*Fig. 5*). The smallest diameter of this fiber determines the acceptance angle.

The intensification of light represents an important application of the tapered fiber. Light is passed from the large end to the small end, at which there is an increase in the light flux per unit area. However, all entering light must be within the smaller acceptance angle of the larger fiber end. Probably the most frequent error in this connection lies in an attempt to condense a Lambertian area of light. A Lambertian-source plane (as on matte white paper or phosphors, to cite two approximate examples) looks equally bright from all directions. Nevertheless, only the light within the acceptance cone is passed on through the fiber—the rest of the light spills out the sides and is lost.

Fibers usually clad by glass

Actually, single fibers are limited in application, and most fiber-optical devices take the form of bunches of fibers. When fibers are bunched together, light jumps from one fiber to the next unless these fibers are clad. For this reason, among others, optical fibers are usually made with a glass cladding that has a low refractive index and is thick enough to insulate the fibers from external disturbances.

Although the cladding is most frequently glass, it can also be of some other material, such as plastic. When the fibers are arranged in arrays, the cladding is fused and bonds the fibers together to form a solid mosaic.

Each fiber in such a mosaic usually has a second cladding of opaque material to absorb light outside the acceptance angle "extramurally." In *Figure 6*, for example, the phosphor coating on the mosaic emits light in all directions. The light inside the acceptance angle forms

an image, while the light outside this angle is scattered. In observation by eye within the acceptance angle, the scattered light cannot be seen. In direct printing on film, it lowers the contrast. The second, opaque, "extramural"-absorption cladding prevents this degradation.

With rare exceptions, fiber-optical mosaics cannot form an image or transport an unformed image. A lens forms an image by making a phase transformation on a wavefront. Although fibers carry phase information, because of the multiplicity of "waveguide" modes and hence of the propagation constants, each fiber acts like a diffraction grating. Moreover, minute diameter variations from fiber to fiber produce enormous phase changes. For these reasons, the end surfaces of fiber optics should be an image surface, located in the image plane of a lens or with an image directly formed on the ends, as by a phosphor coating.

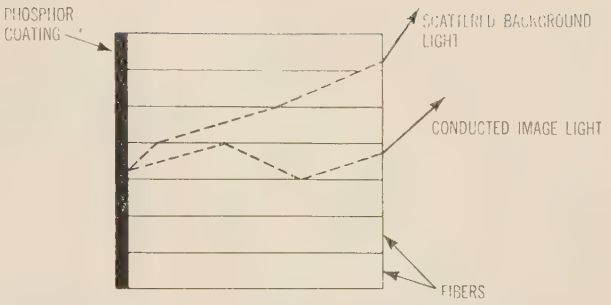


FIGURE 6: A second, opaque cladding should be added to this mosaic to keep scattered background light from lowering the contrast.

"Insect eye" produces image

An exceptional mosaic that can produce an image is made up of tapered fibers arranged like those in the eye of an insect. Each fiber has a narrow acceptance angle and looks in a different direction. The result is a pattern of light and shade that forms a visual image.

Probably the simplest fiber array is the "light conduit" —an unaligned, flexible bundle of single fibers that serve only to transmit light. Though it is generally considered a fiber-optical device, strictly speaking it isn't, since the "optics" in fiber optics refers to image-carrying devices.

Special illuminators form a class of light conduits. The simplest is a conduit with one end round and the other end rectangular. Beyond this, the field is limited only by the designer's imagination and the manufacturer's patience. An auxiliary device frequently used with illuminators is a mixing chamber to even out illumination irregularities over a given area.

Flexible fiberscopes are light conduits in which the bundles of fibers are aligned. At the present state of the art, the resolution of this device is not necessarily related to fiber size, because the alignment is not always perfect. Also, the safe bending radius of the fiberscope depends mostly on construction, packaging, and surface treatment rather than on fiber size.

Image conduit has fused fibers

An "image conduit" is like the fiberscope, except that the fibers are fused together and there is little or no flexibility. It can, however, be bent with a torch to conform to any desired path. Into an "illuminating image conduit," a uniform light field can be injected from the side and is carried in separate channels in the direction opposite to the image's to illuminate an object too close for other types of lighting (*Fig. 7*). Under certain conditions, standard image conduits can also be illuminated from the side, with the light and the image using the same channels. However, this approach generally produces poorer contrast.

"Optical millefiori" are relatively small image conduits. They come in a variety of sizes and shapes and may or may not be tapered. The maximum number of fibers in this device has arbitrarily been set at 10,000. The smallest units have some flexibility and all are easily bent with heat. They can be used singly for simple images such as dials and can be pieced together for more elaborate jobs.

"Optical mosaics" are solid, fused blocks of aligned fibers. They can be thick or thin, large or small, and tapered, distorted, bent, or otherwise shaped. A special type is formed as sheet material.

Transmission through these mosaics is affected by several factors:

- There is surface reflection off both entrance and exit areas.
- The full area of the mosaic is never used, since the cladding may occupy 8-30 per cent of it.

The numerical aperture and the distribution of the incident light determine the transmitted fraction of the angular distribution.

There is invariably some absorption or scattering of light, though it is usually negligible in thin pieces, except at the ends of the transmission spectrum. When extramural absorption is used, more of the image light is absorbed, and the nominal numerical aperture decreases somewhat. The image itself may be just as intense, however, as that from a clear piece of the same numerical aperture, and contrast may be much improved.

In a "two-image" mosaic, the fibers are longest in

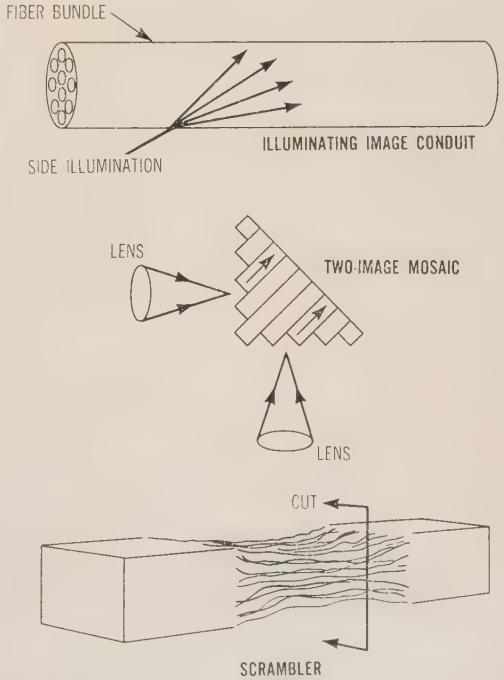
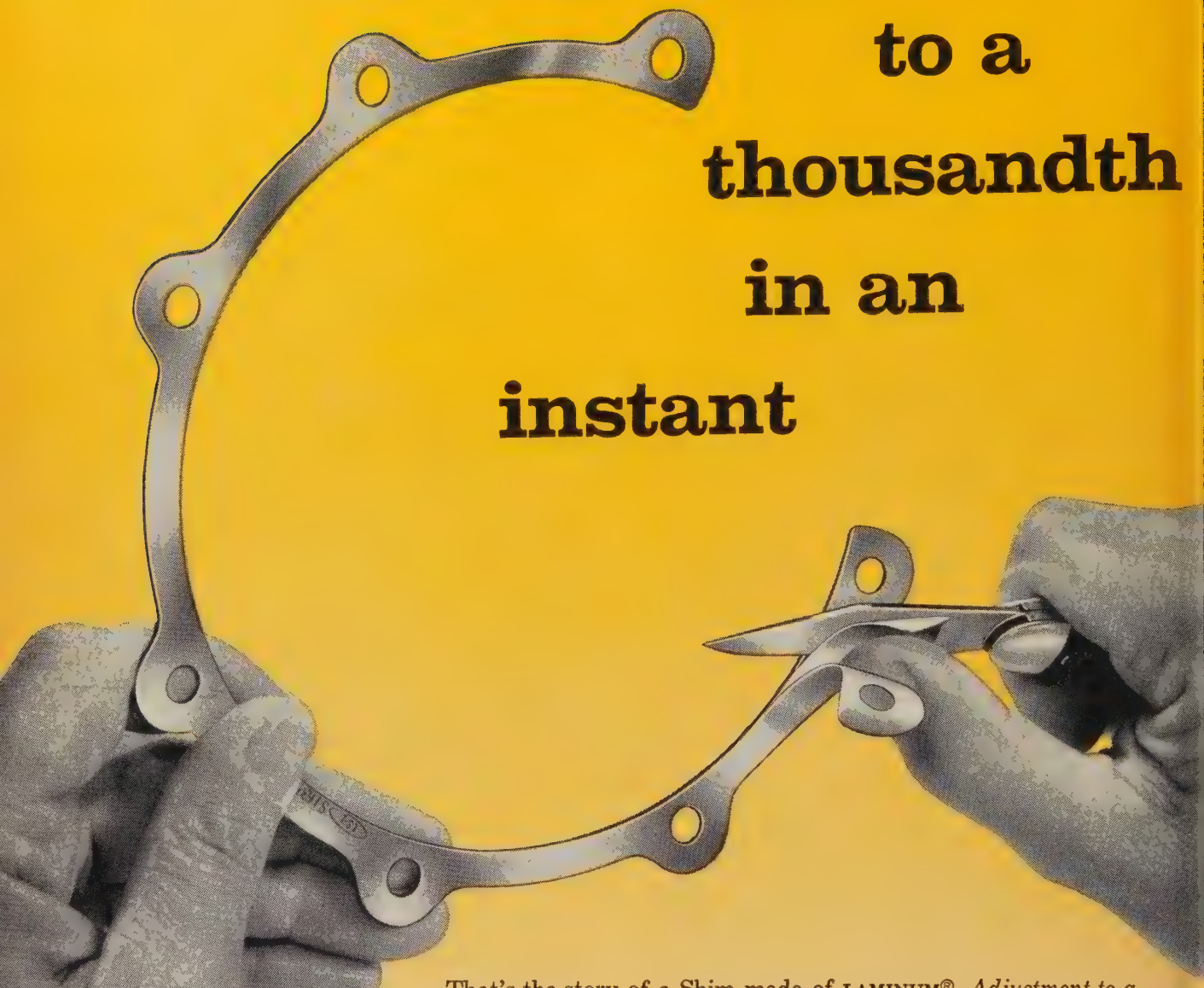


FIGURE 7: Three types of fiber-optical mosaics.

Adjustment to a thousandth in an instant



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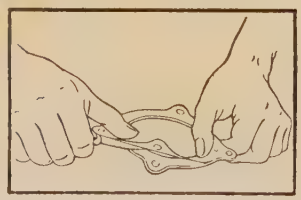

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Fiber-Optical Devices

	Application	Advantages	Limitations
Flexible fiberscope	medical endoscopes, industrial borescopes, remote dial reading, fire detection	flexibility, high numerical aperture, good resolving power in small diameters, no loss of resolution due to vibration	breakage, low resolution in large diameters in comparison with conventional optics, low transmission in long lengths
Image conduit	same as flexible fiberscope's when no permanent flexibility is required (rotary joints can give limited flexibility)	less breakage than flexible scopes, less costly	
Optical millefiori	combining images (as in dial reading), single-line handling (as in line-scan borescope), image dissection		
Mosaic sheet	single-line handling (as in converting a line to a curve for facsimile image dissection)		
Optical mosaics	image faceplates for tubes, field-curvature correctors magnifiers, light-intensifiers (demagnifiers), projection screens & other ground-glass replacements, image rotators	high NA (total resolution), conserves weight & space, no internal adjustments liable to get out of focus, fine-grained ground glass with controlled spread	zero working distance surfaces collect "trash" that is in focus
Single fiber	single-bit data handling, illumination, matrix re-mapping, optical waveguides, optical delay lines, optical phase comparators, broad-band optical signal channel		

the center and progressively shorter as they extend towards the sides. The end of each fiber is cut square to its axis, much in the manner of a Fresnel lens. This device can carry images from two sources. A practical disadvantage is that its staggered surface must not be touched, or the pockets will fill up with grease.

Scrambler middle is disoriented

The fiber-optical "scrambler" is like a fiberscope except that the middle section of the loose fibers is deliberately disoriented and then potted and sawed. Each half can then code a picture that can be decoded by the other half.

Optical mosaics are often sealed to glass or metal for electronic applications. Most of the current mosaics are designed to seal to G-12 glass, Sylvania #4 metal, or the expansion equivalent. There is a good possibility that Kovar mosaic seals will soon be available.

These mosaics behave much like any other glass, except that cracks in them tend to run across the mosaic, so that there is an increased susceptibility to flaking. Otherwise, they can be ground and polished. The user should first check with the manufacturer, however, since many mosaics are supplied with an essential coating that must not be removed. For vacuum-tube fiber windows, a conservative rule calls for a diameter-thickness ratio of 16.

Because optical mosaics are two- and sometimes three-glass systems, annealing instructions from the manufacturer are required. Some mosaics can be processed completely below the annealing temperatures of all components. Others have two or three annealing ranges, which should be observed with care, since excessive temperatures can cause devitrification, porosity, surface ripple, sagging, or discoloration.

APPLYING FIBER OPTICS

by W. B. Krakows and A. M. Baker, *Manager, Fiber Optics Products, & Research Associate, Chicago Aerial Industries, Inc.* *

WHEN ALL FIBERS in a fiber-optical bundle or a fused plate are in parallel, a picture can be transmitted from one end to the other. The resolution of the picture depends on the pitch of the fibers, or distance between their centers, provided the light in each fiber is contained within itself. The contrast of the reproduced image, as compared with that of the original, depends on fiber diameter and the transmission efficiency of the fiber-optical device. The ability of fiber-optical mosaics to gather light rays and transmit them with high efficiency can sharply decrease photographic exposure times.

In the application of fiber optics to image transmission

* Chicago Aerial Industries, Inc., 550 W. Northwest Highway, Barrington, Ill.

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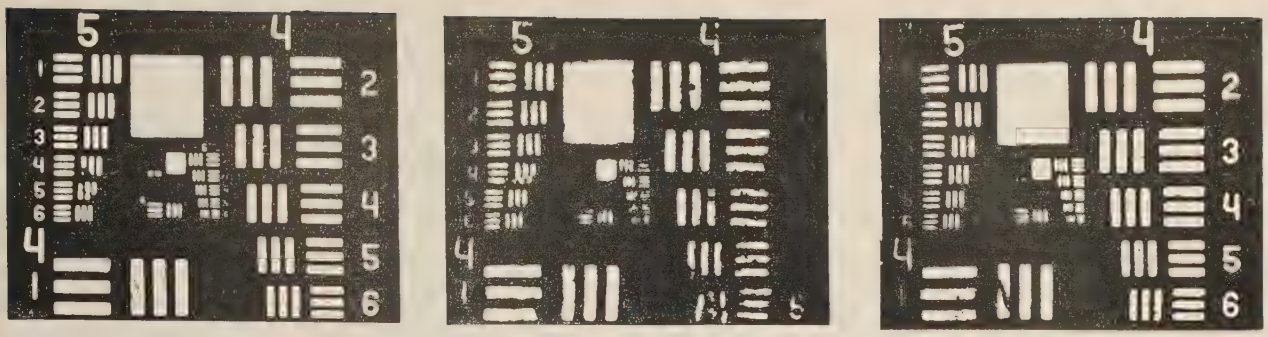


FIGURE 1: Resolution target of 114 line pairs per millimeter as photographed by a microscopic camera with diffuse illumination and an objective-lens numerical aperture of 0.65 (left) and as it appears when it lies on the microscope stage and is covered in direct contact by a single fiber-optical plate with five-micron fibers and a numerical aperture of 1.01 (center) and by two such plates randomly stacked on top of each other (right). The resolution of both the single plate and the stacked plates is much lower if there is even a few thousandths of an inch separation from the target. The magnification is about 70×.

and conversion, several practical factors must be considered. Resolution naturally is of prime importance. The pitch of the fibers (which determines the resolving power) basically depends on the size of the individual fiber. The limit on fiber size is at the lower end of the scale, which ranges down to less than five microns.

The dimensions of the core plus those of the cladding establish the center-to-center pitch of adjacent fibres. The relationship between core size and resolving power is non-linear, because a fixed minimum separation must be maintained between the perimeters of adjacent cores. Because of manufacturing problems, the ideal separation is not reached in practice.

Fiber pitch is directly related to resolution when the fiber shape is constant. For a pitch of 5¼ microns, the fiber core currently has a diameter of 4½ microns. A bundle of such fibers has a resolution of 114 line pairs per millimeter with a high-contrast target (*Fig. 1*). Generally, a fiber size of 10 microns gives a photographic resolution of 57 lines per millimeter, and the results with other sizes can be considered to be proportional to this value.

As fiber pitch is reduced, light transmission drops most noticeably at extended lengths. So far, this effect is not predictable. The reductions in fiber size also tend to magnify the effects of material variations and imperfect manufacturing control.

Nesting round fibers ups efficiency

The ratio of core-glass area to total plate area is important because the core transmits useful light, while the sheath transmits unwanted rays (*Fig. 2*). By nesting round fibers without sheathing around the core, an area efficiency of 90.6 per cent could theoretically be achieved, but present manufacturing conditions dictate that the area of the core glass be about 80 per cent of the total.

A circular cross-section is ideal for many fiber-optical applications. It is possible to improve the area efficiency with hexagonal or square fibers, but so far these are difficult to fabricate. When a fiber shape radically departs from a regular polygon or a circle, cross-talk occurs between fibers as light flux escapes from the imperfect corners to adjacent fibers and the resolution drops.

We are now making fibers that approach a circular

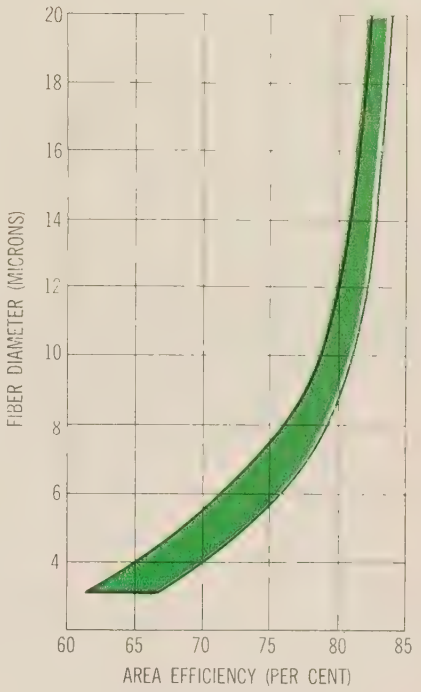
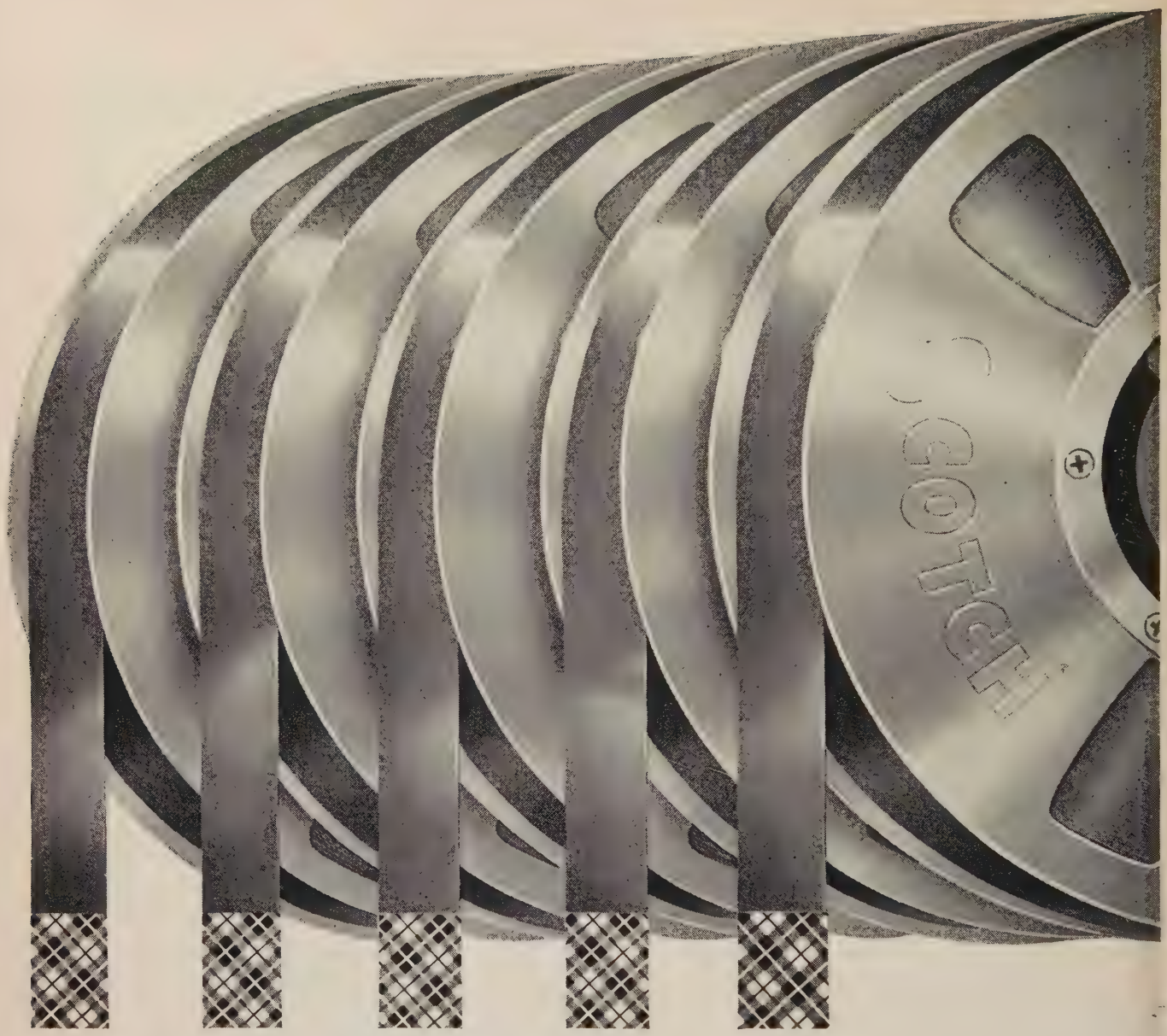


FIGURE 2: Generally used area efficiencies of fused, round fibers.

Light Loss From End-Surface Reflections in Typical Optical Fibers in Air

Refractive Index	Light Loss (per cent)
1.54	8.9
1.62	10.9
1.69	12.8
1.73	13.7
1.76	14.6
1.80	15.7
1.85	17.0



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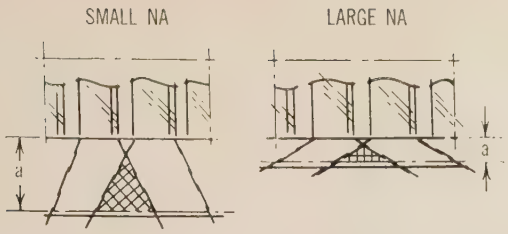

◀ **FIGURE 3:** For a given fiber size, the depth of focus of a fiber-optical element increases as the numerical aperture decreases.

cross-section. The maximum-minimum dimensional ratio of these cross-sections normally is less than 5:4. The usual accuracies for individual fiber areas are ±20 per cent down to ten microns, while between ten and five microns, they range from ±20 to ±40 per cent, depending on the type of glass.

In current fiber-optical devices, which often have more than 3,000,000 fibers per square inch, perfect alignment cannot be guaranteed over an extended surface. Without special attention, the misalignment of fibers in a fused, ¼-in. plate does not exceed 0.005 in. When checked by a precision straight-edge, 80 per cent of the fibers are within ±0.002 in. of perfect alignment. Closer dimensional control is possible—if you are willing to pay for it and allow the manufacturer extra time.

Two factors lower resolution

When an image passes through two fiber-optical elements of identical resolving power and stacked in series, resolution is degraded by two factors:

- The random orientation of the fibers of one element with respect to the other's produces a statistical resolution loss of 0.707 times the individual element resolution in lines per millimeter. (For three identical elements in series, the resolution is 0.578).
- The lack of contact between all fibers at the junction of the elements is not perfect. To minimize losses, this contact must sometimes be within a few wavelengths of light.

When two fiber-optical elements are coupled, a loss in light also occurs because of surface reflection at the fiber ends. These losses can be reduced, however, by using a liquid or plastic with a high index of refraction and optically similar to the core glass.

The refractive index of glass cladding normally falls between 1.54 and 1.47. For a large numerical aperture, the index of the core should be substantially higher. In practice, core indexes ranges from 1.5 to over 1.9 (in discrete values) since only certain glasses are suitable for fiber optics.

Losses follow Fresnel's formula

Surface-reflection losses at the ends of fiber cores follow Fresnel's classic formula for reflection on untreated dielectric surfaces. The greater the difference between the refractive indexes of the external medium (usually air) and of the glass core, the higher the reflectivity.

The *Table* gives the end-reflection losses for both ends of typical fiber materials in air. These losses are accurate for incident angles of the entering ray, or acceptance angles, from zero to 30 deg.

The numerical aperture limits the conical angle of the ray bundle at the ends of the individual fibers in an effect somewhat similar to the depth of focus of a lens. When the aperture and the conical angle are small,

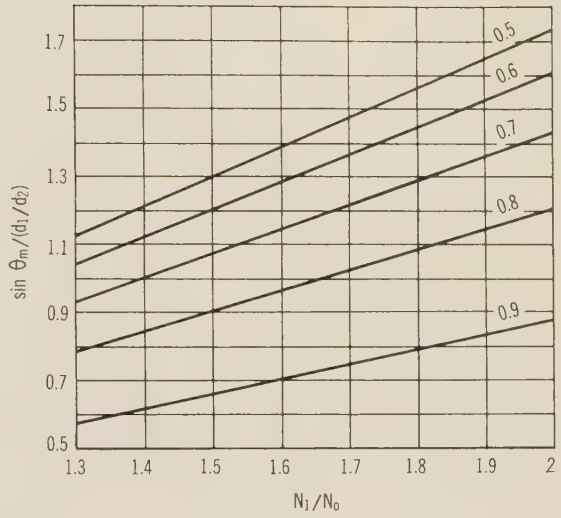

FIGURE 4: Refractive-index ratio N_1/N_0 of fiber core to surrounding medium vs maximum entrance and exit angle (θ_m) and smaller and larger diameters (d_1 and d_2) of a tapered fiber used as a light intensifier for various ratios of N_2/N_1, where N_2 is the index of the glass cladding.

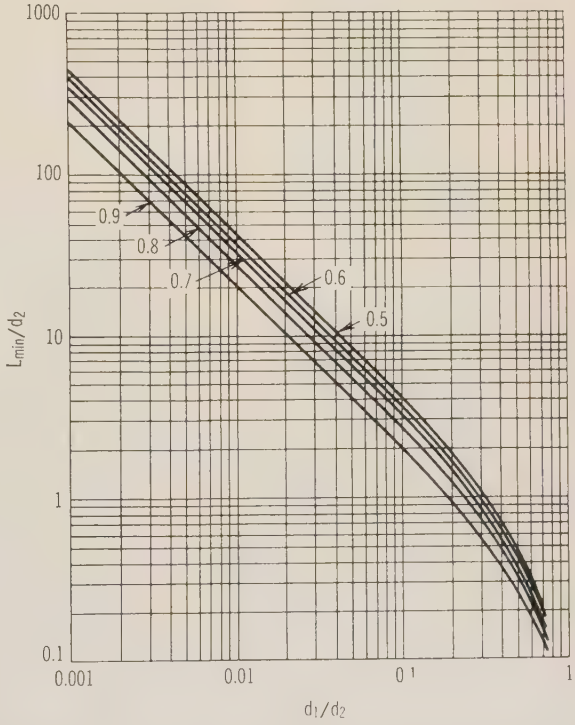

FIGURE 5: Diameters of fiber-optical light intensifiers vs minimum length necessary to transmit all light entering the large end within θ_m for various ratios of N_2/N_1.

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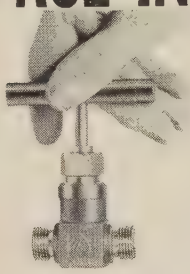

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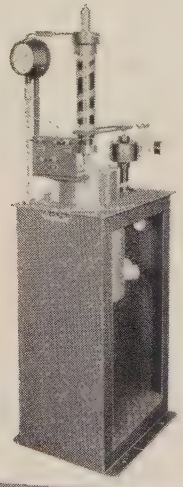

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Information Required by

Parameter
Fiber size
Fiber shape
Packing efficiency
Light transmission
Numerical aperture
Coefficient of expansion
Broken fibers or voids
Fiber inclination
Fiber-bundle size
Sealing
Chemical poisons
Geometry of fiber-optical element
Intended application

the ray bundle proceeds a greater distance from the end surface before appreciably overlapping ray bundles of the surrounding fibers (*Fig. 3*). This effect is used to advantage in probes and in devices in which a film or document moves across the face of the fiber-optical element, which would scratch if contact were made.

Dynamic scanning regains some detail

A fiber-optical plate interposed in the light path of an optical system has a significant image-degrading effect, because the image is dissected, or quantized, by the plate

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Fiber-Optical Manufacturers

Remarks
10 microns equals 57 lines per millimeter photographic resolution; other values are proportional
9:10 is best roundness; 8:10 is usual; 5:1 is required for some glasses
usually 65-80 per cent, depending on fiber size (Fig. 2)
specify particular color values outside 0.46-0.75-micron range
when fiber-optical surfaces are examined (sampling areas are 0.1 diameter or larger), the minimum area efficiency is usually specified 10 per cent lower than the nominal area efficiency (Fig. 2)
this is the perpendicularity, or alignment, of the finish surfaces to the major fiber axis; unless specified this tolerance is ±1 deg.
normal tolerances are ±0.015 in. up to two inches, thereafter ±0.030 in. unless specified; radial tolerances usually are ±1/16 in. unless specified; normal flatness is 10 fringes at 5800A for any 1½-in.-diameter area except within 1/16 in. of the plate edge
normally hermetically tight up to 10^{-6} mm Hg
cite any known glass-formers that might poison surfaces to be deposited on the fibers or indicate such surfaces, so the manufacturer can propose the glass combination best suited to application; indicate any kind of caustic atmosphere and its concentration
if possible, give a sketch of the application
when in doubt concerning proper values of the preceding parameters, describe the application and give resolution requirements and other available data

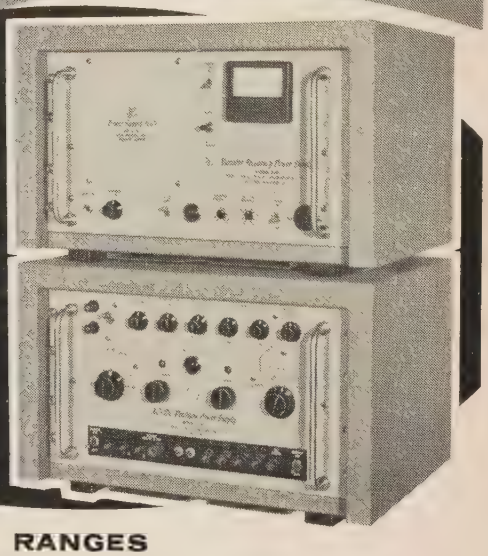
into discrete, small areas corresponding to the individual fibers. Some of the lost detail may be regained by dynamic scanning—a rapid periodical shifting of the fiber plate back and forth over the image in order to center the fibers over every small bit of detail. The action of the eye adds all the slightly differing images together (time-smoothing) and the resulting image appears to contain more detail.

A tapered optical fiber can be used as a demagnifier, or light intensifier. The maximum angle at which a ray can strike the axis of the large diameter (d_2) without refractive loss is:

$$\theta_m = (d_1 N_1 / d_2 N_o)\sqrt{1 - (N_2/N_1)_2}.$$

AC-DC Precision Power Supply

Model 2120 PROVIDES Variable Voltage, Current & Frequency



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Kaylock® 'captive washer' nut gains wide acceptance

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Saves Assembly Time. Kaylock HW14's cut extra motion required to put washer on bolt. Washer can't drop off during application or removal. Cuts time lost looking for wayward washers..*to zero!* *Safer, too!* Kaylock HW14 "captive washer" nuts employ the same, sure elliptical locking principle to prevent vibration hazards. The Kaylock HW14 is a development of Kaynar Mfg. Co., Inc., world's oldest and largest manufacturer of lightweight, all-metal self-locking nuts. Write today for the new Kaylock HW14 Brochure—or call your nearest Kaylock representative!

The Kaylock HW14 is available in size -02 (shown above) and in other sizes to -6

View of Kaylock HW14-3 and washer prior to assembly.

Assembled HW14-3. Integral, free-spinning washer can't drop off. Only one part to handle instead of two.

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where d_1 is the small diameter and N_0, N_1, and N_2 are the refractive indexes of the outside medium, the core, and the cladding, respectively (*Fig. 4*).

Intensifier must accept light at up to θ_m

A light intensifier must accept all light that strikes the large-diameter face at up to θ_m. For fixed fiber diameters, the minimum fiber length necessary to meet this requirement is given by (*Fig. 5*):

$$\frac{L_{min}}{d_2} = \frac{1/2\,(1 - d_1/d_2)\cos\theta_m}{\frac{d_1}{d_2}\sqrt{1 - (N_2/N_1)^2} - \sin\theta_m}$$

For small values of θ_m, this equation reduces to:

$$\frac{L_{min}}{d_2} = \frac{1 - d_1/d_2}{2\frac{1}{d_2}\sqrt{1 - (N_2/N_1)^2}}.$$

A fiber bundle often must relay light from the image plane of a lens to another location. To accept all the image light in an off-axis position, the fiber must accept light from all points of the lens aperture (*Fig. 6*).

Distortion occurs with curved plate

When a fiber-optical plate is curved on one surface to agree with the back focal surface of a lens, distortions occur. *Figure 7*, for example, shows the simplified case of a thin lens whose focal surface is a sphere centered at the lens's rear nodal point. The plane surface of the plano-concave fiber-optical plate is perpendicular to the central axis of the curved surface. The result is a radial distortion (D_1) that is a function of the curve and the off-axis position of the ray. It is given by: $D_1 = \cos\phi - 1$, and is negative, so that you get a barrel-shaped figure of two parallel lines centered on-axis. It increases rapidly with the field angle.

For a double-concave fiber plate with dissimilar curves and again assuming spherical surfaces with the pupil points at the center of curvature, the net resultant distortion is (*Fig. 8*):

$$D_2 = \cos\phi'/\cos\phi'' - 1.$$

This equation shows that, while distortion depends on the field angle, a change in the conjugate distance alters the field angle for a given off-axis position. Therefore, either positive (pin-cushion) or

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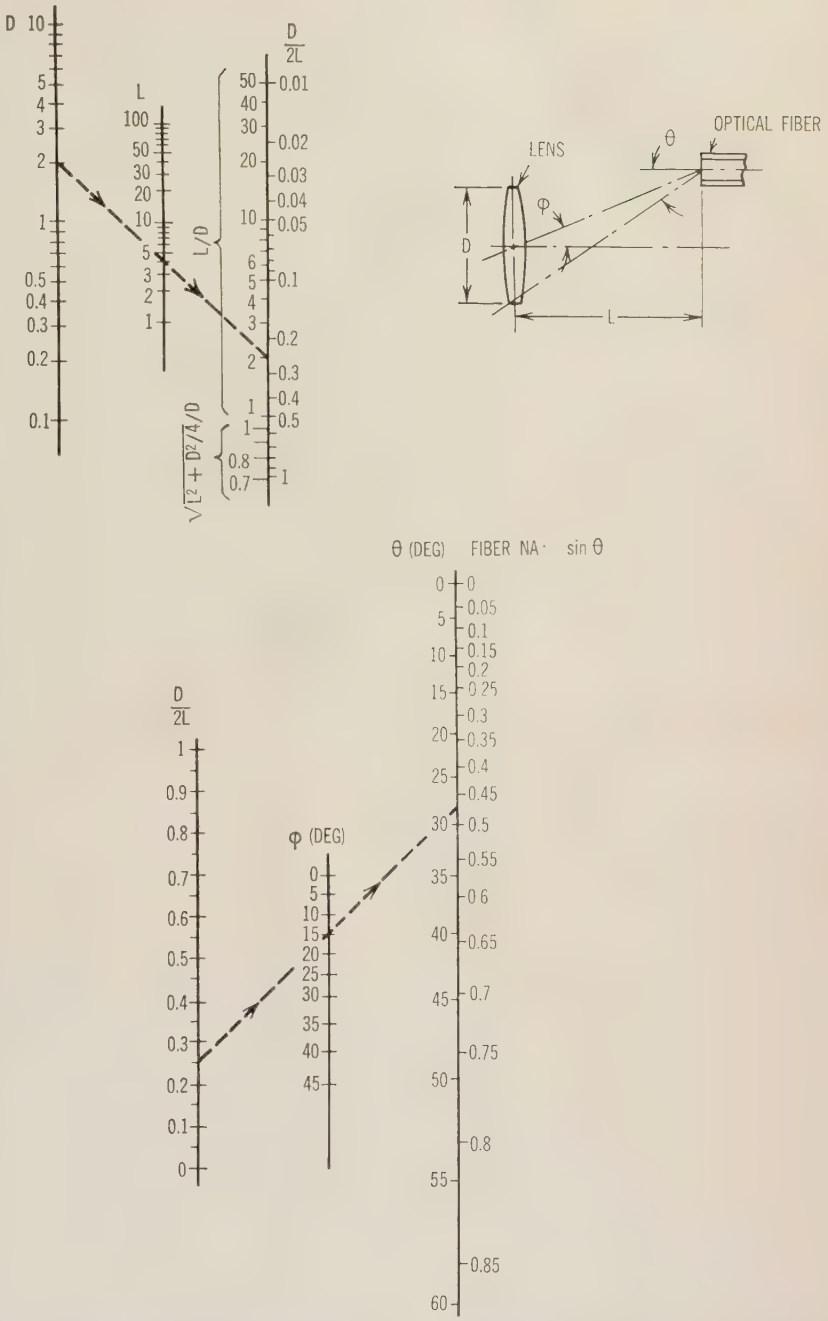

FIGURE 6: Nomograph for a fiber bundle relaying light from the image plane of a lens to another location. For this simple lens, the fiber is off axis at angle θ and must gather light through angle ϕ. The basic relationship for this lens is: $\tan \theta = \tan \phi + D/(2L)$.

negative (barrel) distortion is possible.

Under some conditions, electron-beam devices can impart positive distortion to the electron image that compensates for the negative distortion of the fiber-optical face. In devices like cascaded electrostatic image converters, distortion from the first curved surface can be eliminated if the second surface has the same curvature and operates in conjunction with a similar set of electron optics. Plano-concave fiber optics for use in a dynamic mode (scanning) should have large radii of curvatures so that distortions do not interfere with image require-

ϕ (deg)	D_1
45	0.2930
30	0.1339
14.5	0.0318
9.5	0.0140
7.25	0.0079
5.75	0.0050
4.75	0.0035
4.10	0.0026
3.50	0.0019
2.87	0.0013
1.43	0.0003

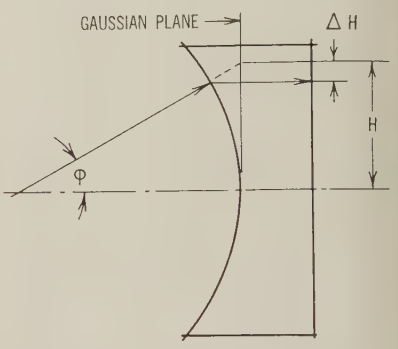

FIGURE 7: Geometric distortions occur when a fiber-optical plate is curved to agree with the focal surface of a lens, as in this simplified case. The distortion (D_1) increases rapidly with the field angle.

ments. In fact, the radius preferably should be infinite, providing a flat surface.

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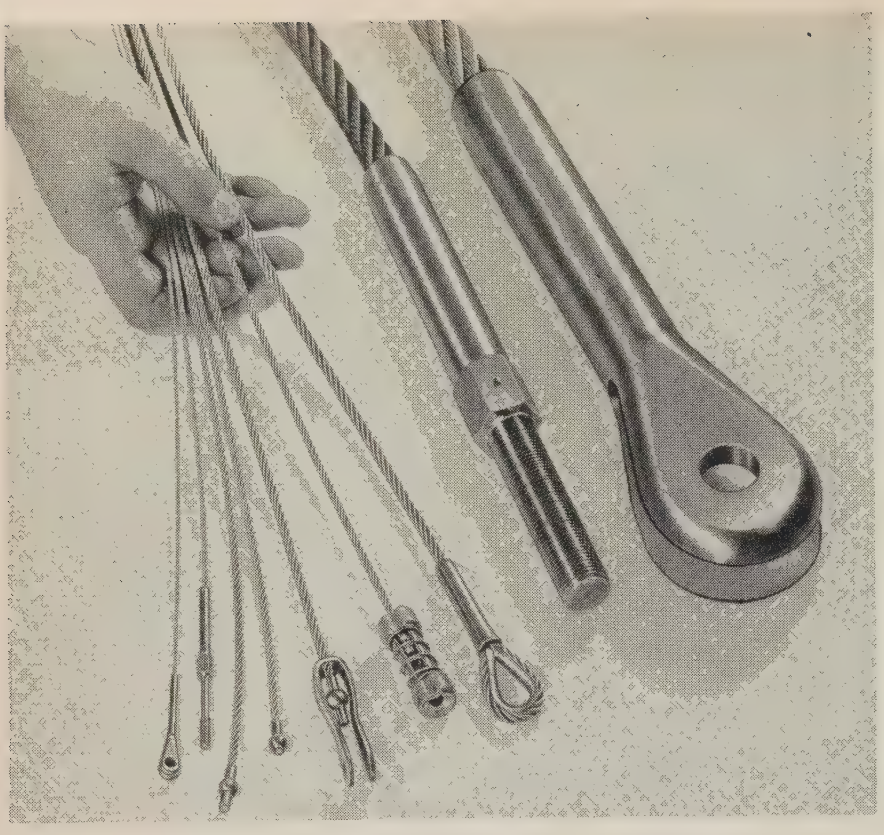

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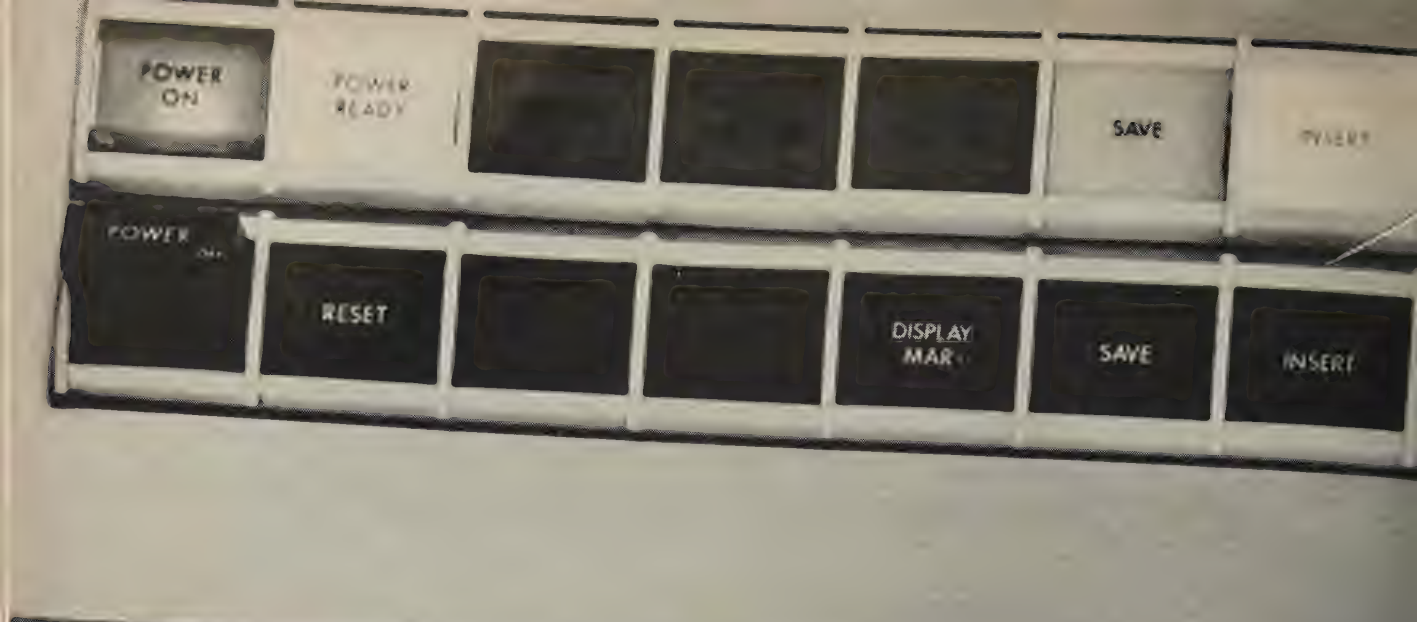
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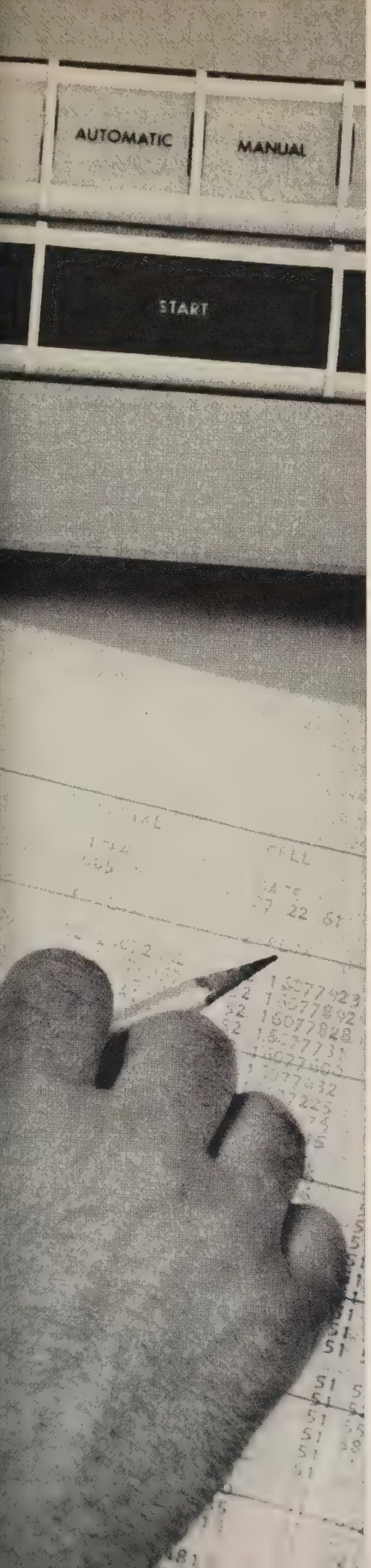

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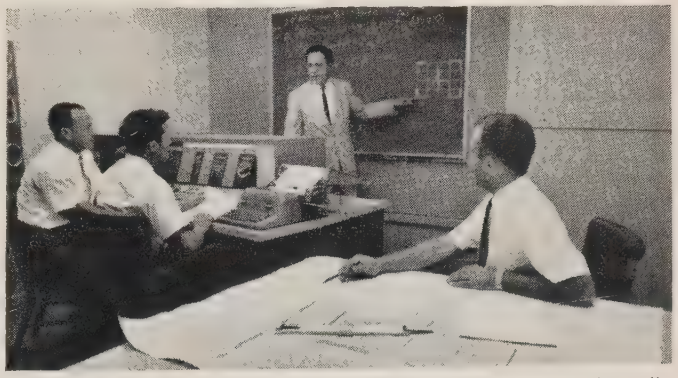

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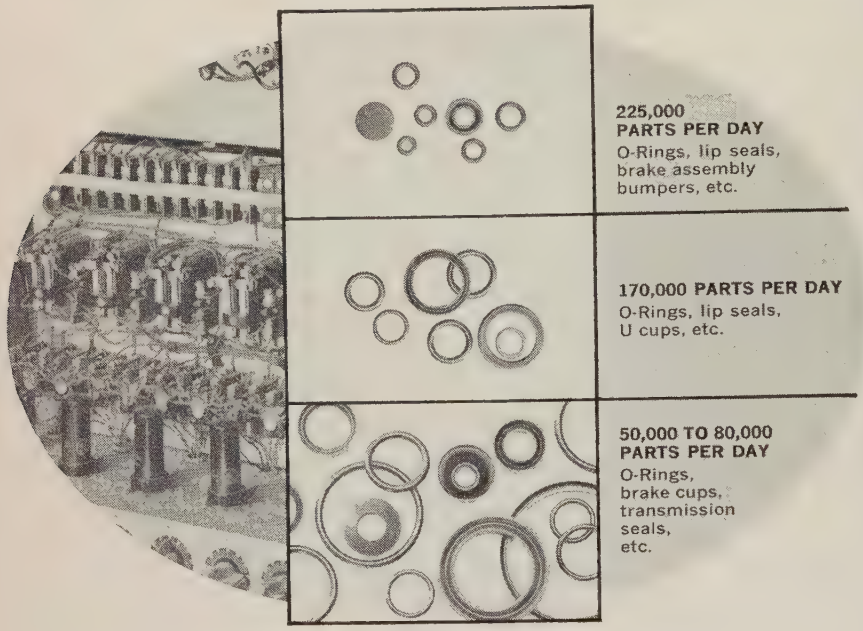

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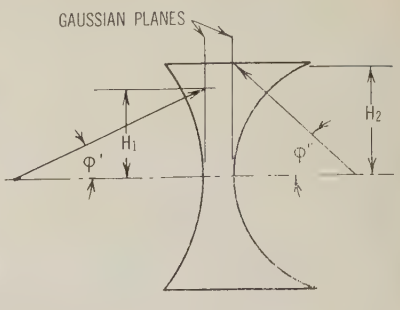

FIGURE 8: Distortion also occurs in the case of a fiber plate with double-concave curves of different radii.

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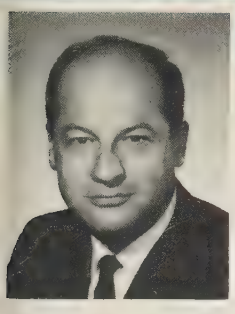

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Manufacturers of the Electrosnap and Hetherington full line of switches, controls and indicators for all military and commercial applications. All standard units stocked for immediate delivery by leading [illegible]

Check Inquiry Form on Page 131

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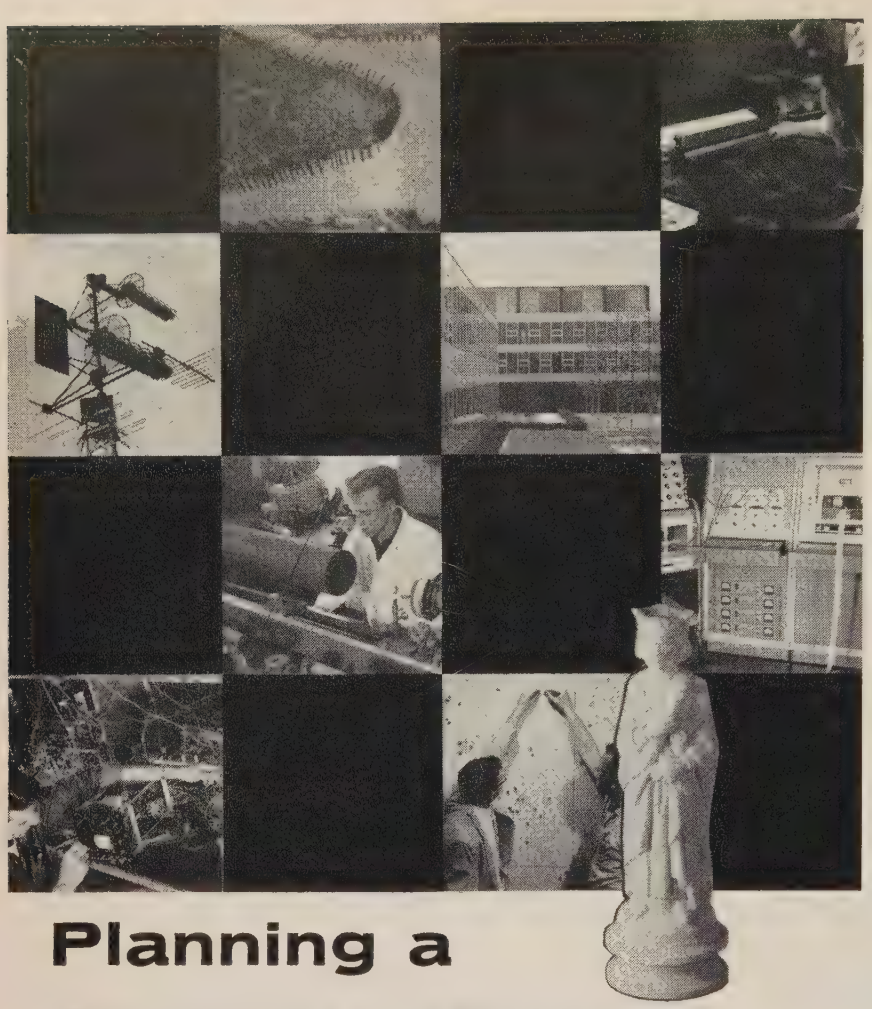

Planning a Strategic Move?

Many unusual opportunities are available to qualified engineers and scientists capable of assuming responsible positions with HRB-Singer. One of the country's leading R & D organizations, HRB continues to expand its research and development activities at a rate far surpassing most electronics industries. Top scientific personnel continue to make state-of-the-art advancements in the development of complete electronic systems but a constant supply of new talent is essential to the continued growth of any organization.

HRB-Singer, the acknowledged leader in the development of airborne infrared reconnaissance systems, provides extensive R & D facilities in an atmosphere conducive to professional development.

In addition to the many technical challenges, HRB provides an exceptional employee benefit package which includes Company financed graduate study at the Penn State University, free hospitalization and life insurance along with an extremely liberal vacation program.

If you are interested in learning more about career opportunities at HRB-Singer, write George H. Rimbach, Supervisor of Personnel, Dept. R-4.

HRB

HRB-SINGER, INC.

A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY

Science Park, P.O. Box 60, State College, Pa.

IMPORTANT

In filling out "Employment Inquiry Form" be sure to print clearly. When you check more than one company, we must photostat the form so that each company receives a copy.

PROPER PROCESSING DEMANDS LEGIBILITY

CLASSIFIED

JOB HUNTING? MAILING RESUMES? SALES LEADS?

INVEST $1.00 for any of the following:

1. Mailing address Directory of over 500 R&D Engin. & Manuf. firms located at these Industrial Centers: Route 128 & 3, Needham, Waltham, Natick Cambridge, Burlington, Newton & Boston.
2. Instructions on "Aids to Better Employment and Interview Behavior and Procedures."
3. Sample Resume including "write it yourself aids."

KENMORE VOCATIONAL PUBLICATIONS
520 Comm. Ave., Boston 15, Mass.

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Do you share his reluctance to accept the accepted?

Doubt is his dogma. He questions everything, takes nothing for granted — not even his own answers.

Do you share his stubborn skepticism? Then come to Northrop, where the breadth and variety of projects give ample scope to the most determined questioner. Northrop's divisional organization makes it possible to support a broad range of programs from countermeasures systems and airborne computer design to techniques for aero-space deceleration and re-entry, and the maintenance of a total human environment in space.

Top priority, just now, goes to senior aerodynamicists and computer circuit designers. But whatever your specialization, if you're the kind of man Northrop needs, there'll always be an opening for you. Why not get in touch with us today and find out more? Just write to Northrop Corporation, Post Office Box No. 1525, Beverly Hills, California.

NORTHROP

AN EQUAL OPPORTUNITY EMPLOYER

Check Inquiry Form on Page 131

DEVELOPMENT ENGINEERS

Advanced Motors, Generators, Solid State Circuit Design

Several fine opportunities are now available in expanding project areas.

Generator Development Engineer

This position requires a man for design and development work on high speed alternators. A comprehensive knowledge of alternator design is needed with special emphasis on high speed, high frequency machines. BSEE and 3-5 years experience required.

Development Engineer for Advanced Motors

Prefer physicist, or EE, for work involving electromagnetic theory as applied to advanced electric motor studies. This work involves investigation of electrical, thermal and mechanical phenomena, with immediate assignment dealing with solid rotor motors.

Work will involve machine studies using modern computer techniques. Requires 3-5 years experience.

Development Engineer for Solid State Circuit Design

This work involves design and development of solid state power conversion equipment. Experience is needed in the operation of silicon controlled rectifiers in power handling circuits. Requires BSEE and 3-5 years experience.

Garrett is an "equal opportunity" employer. Send complete resume to Mr. Thomas Watson.

GARRETT

AIRESEARCH MANUFACTURING DIVISION

9851 So. Sepulveda Blvd., Los Angeles 45, California

Investigating Employment Opportunities?

Want more information about employment opportunities offered by companies advertising in this issue? Then be sure to give complete data about your job interests, experience and education when filling in the "Employment Inquiry" form.

Although not an application for employment, it provides employment managers with information to evaluate your capabilities—and in turn give your request immediate consideration.

Check the "Employment Inquiry" form for details.

Check Inquiry Form on Page 131

ENGINEERING and SALES in CONNECTICUT or FLORIDA

The growing role of Pratt & Whitney Aircraft in the national aerospace program is apparent in the research and development projects and long-range product planning being conducted at their East Hartford, Connecticut Facility and Florida Research and Development Center.

At present, openings exist at various experience levels in research, design, development, and sales for engineers and scientists (BS through PhD) with experience in the following fields:

- ROCKETS
- NUCLEAR POWER
- ROTATING MACHINERY
- MAGNETOHYDRODYNAMICS
- FUEL CELLS
- CRYOGENICS
- GAS TURBINES
- HYPERSONIC PROPULSION
- THERMIONIC & THERMOELECTRIC CONVERSION

ENGINEERING

Connecticut and Florida Operations

ANALYTICAL ENGINEERING and *APPLIED RESEARCH*

ELECTRICAL ENGINEERS:
Analytical and experimental investigations in advanced rotating machinery, including cryogenic and very high temperature, high speed machines.

NUCLEAR ENGINEERS:
Analytical studies and preliminary design of advanced concepts in reactor systems and components.

MECHANICAL • AERONAUTICAL • CHEMICAL ENGINEERS:
Performance and optimization studies of all types of advanced power and propulsion systems and vehicles, including fuel cells. Reliability studies of advanced designs.

PHYSICAL CHEMISTS • ELECTROCHEMISTS • PHYSICISTS:
Anaytical and experimental research in plasma physics, gaseous electronics, solid state physics, electrolytes and other fields related to development of energy conversion systems.

METALLURGICAL • CERAMIC • MATERIALS ENGINEERS:
Analytical and experimental studies of materials for application to all types of propulsion and power systems.

DESIGN ENGINEERING

MECHANICAL • AERONAUTICAL • CHEMICAL ENGINEERS:
Mechanical Design of propulsion and power system components, including electrical machinery.
Elastic and Plastic Analysis of homogeneous and heterogeneous structures.
Analytical solution of problems in applying advanced, unusual structural concepts.
Solution of complex flutter problems utilizing aero-elastic theory.
Analysis of internal flow problems of advanced air-breathing engines.
Analytical design of compressors, turbines and combustion systems for advanced engines and power devices.
Weight analysis of advanced designs.

EXPERIMENTAL DEVELOPMENT ENGINEERING

MECHANICAL • AERONAUTICAL • ELECTRICAL • CHEMICAL ENGINEERS:
Performance analysis of air-breathing engines.
Experimental development of engines, controls, and advanced power systems.
Analysis and experimental development of gas turbine components, including combustion systems, inlets and nozzles, bearings and seals, turbines, compressors.
Design of experimental test facilities, including pneumatic, hydraulic, electrical and instrumentation equipment used in testing air-breathing and rocket engines and components.

INSTRUMENTATION and *CONTROL ENGINEERING*

ELECTRICAL ENGINEERS:
For the application of pressure, temperature, flow and vibration measuring techniques using transient data and digital data recording systems.

SALES

Connecticut Operations Only

As a result of expanded sales activities, a number of positions at all levels of our Sales organization are available for graduate engineers to promote the sales of Pratt & Whitney Aircraft propulsion systems in new vehicles under consideration or development for marine, missile and space applications. These positions offer opportunities in:

PROGRAM PLANNING AND TECHNICAL SALES
Planning of broad sales programs for and the sales promotion of advanced products—entails liaison with government agencies, military and scientific personnel.

SALES ENGINEERING
Responsible for all sales activities with aerospace manufacturers in connection with the application, sale, installation and operation of current and advanced propulsion systems.

SALES OPERATIONS
Analysis and evaluation of advanced programs and markets; the provision of all sales engineering services.

★

Educational Advancement—

East Hartford, Connecticut
Engineers at Pratt & Whitney Aircraft have an unusually fine opportunity to continue their formal education under the United Aircraft Corporation Graduate Education Program with full tuition costs being paid directly to the institutions involved for those who successfully complete the requirements for advance degrees. Excellent courses are offered at the Rensselaer Polytechnic Institute Hartford Graduate Center located a few miles from our East Hartford Plant as well as at other fully accredited schools in Connecticut.

West Palm Beach, Florida
Our Florida Research and Development Center offers post-baccalaureate studies towards a professional degree under the supervision of the College of Engineering at the University of Florida.

Please submit your resume, including minimum salary requirements, to:

Mr. P. R. Smith, Office 75
Pratt & Whitney Aircraft
410 Main Street
East Hartford 8, Conn.

—or—

Mr. J. W. Morton, Office 75
Pratt & Whitney Aircraft
West Palm Beach
Florida

All replies will be handled promptly and in complete confidence.

Pratt & Whitney Aircraft

DIVISION OF UNITED AIRCRAFT CORP.

An Equal Opportunity Employer

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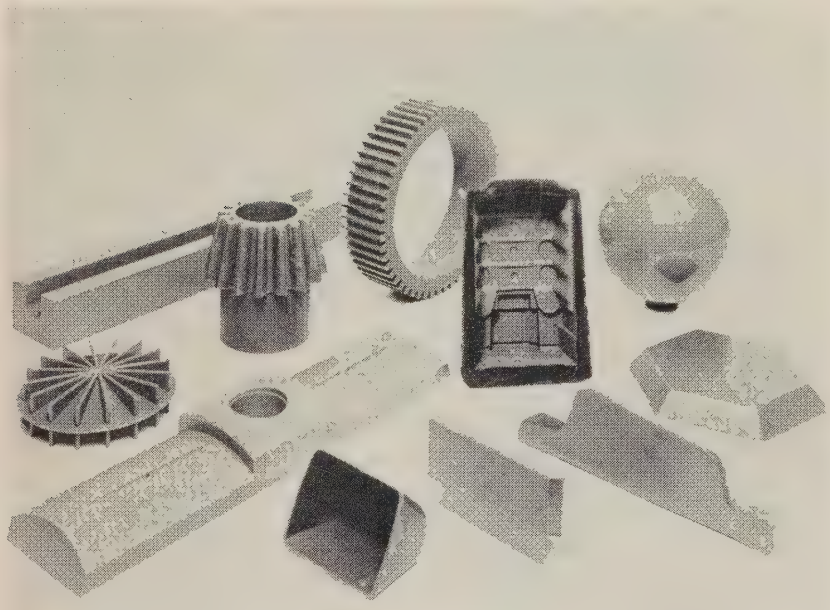
DESIGN DEVELOPMENTS

For more details on the equipment, processes, and facilities described in this section,

LARGE CAST NYLON SHAPES ARE STRESS-FREE

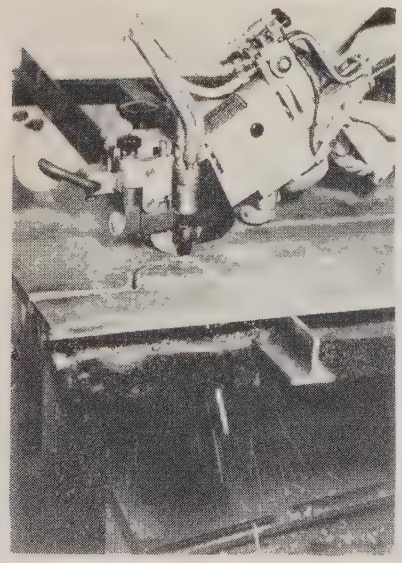


A new casting process for large nylon shapes to be used as lightweight tooling or components has been developed by the Polymer Corp., 2120 Fairmont Ave., Reading, Pa. The MC nylon castings are essentially free of internal stresses and have less of a tendency to change dimension than do injection-molded shapes.

The parts retain their rigidity up to temperatures of 425 deg F. The material is self-extinguishing and provides a tensile strength of 14,000 psi. Dielectric strength is 500 mil. Finishes ranging from high polish to crude sandblast are readily cast.

Polymer's process is similar to conventional metals casting and reportedly can provide shapes of virtually any weight. As the castings are produced directly from monomer rather than from powdered nylon polymer, raw material costs are lowered. **50**

Contour Cutting by Flame



The new 19-lb flame-cutting machine known as the GM-75 Cadet, rapidly cuts metal ranging from light-gauge sheet to two-inch-thick plate. Developed by Linde Co., 270 Park Ave., New York, N. Y., it has a clutch to control the hand-guided cutting.

The Cadet operates at speeds to 30 ipm and can be used with acetylene, propane, or natural gas, After lighting the torch, only one hand is needed to guide the machine and manipulate the controls.

Circles can be automatically cut with a radius rod and a weighted center point. Bevel cutting is done by changing the angle on the torch, which is indicated by a dial calibrated in five-degree increments to 45 deg.

Data on cutting speed, preheat pressure, and cutting oxygen pressure are displayed on the flame cutter. There is also a cutting speed indicator. **52**

High-Speed Programing for Many Automated Tools

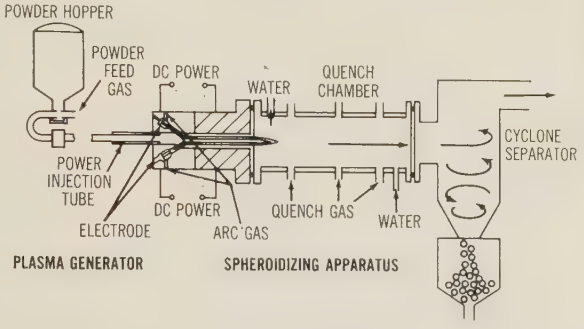
A high-speed computer programing system has been developed by Univac Div., Sperry Rand Corp. 315 Park Avenue S., New York 10, N.Y. and Rohr Aircraft to reduce instruction-writing costs for automated machine tools. The Univac Solid-State 80 or 90 computer forms system's core. Data cards punched from manuscript information (compiled in turn from blueprints) are interpreted by the computer. The computer then punches out manufacture control cards and prints a list of operating instructions.

The system can guide the machine tool control devices of many different manufacturers. Previous numerical control systems were limited to tools from particular companies, Univac says.

Materials and Production

write in item numbers on Reader Service card

Plasma Generator Spheroidizes Refractory Powders



A plasma-arc generator for spheroidizing refractory particles of 100-150-micron size has been developed by Plasmadyne Corp., 3839 S. Main St., Santa Ana, Calif. According to the company, this process can be used in filtering devices, sintering, and the production of free-flowing powder.

The particles, which have melting points in the 2100-3200-deg C range, are spheroidized in a plasma generator, where they are fused at the hyperthermal temperatures produced by the arc-plasma gas streams. The molten spheroids are solidified in a quench chamber and then separated from the gases.

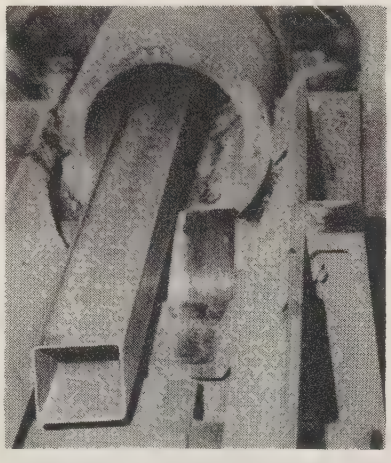
The system can process over 10 lb of refractory powder per hour. It is powered by two power supplies with voltage levels that can be adjusted to suit various plasma gases. Its chief advantage is said to be the uniformity heating of the refractory material. **53**

Hollow, Square Tubing for Lighter Structures

A wide range of sizes of square and rectangular hot-rolled, hollow carbon steel structural tubing is being fabricated to structural steel specs by U.S. Steel Corp., 525 William Penn Place, Pittsburgh 30, Pa. Potential applications, says the company, include missile spacecraft structures and gantry towers.

The tubing has a high strength-weight ratio and is torsion-resistant. As it is hollow, it can be used as conduits for plumbing or electrical wiring.

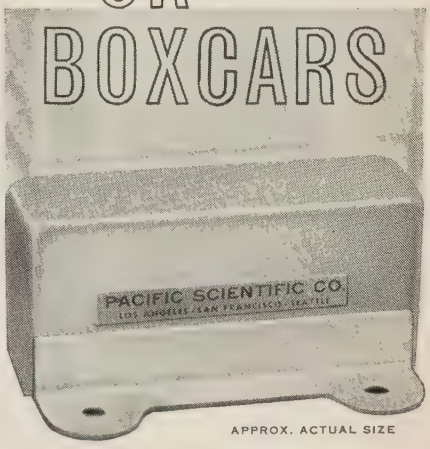
Weight savings of 30-40 per cent over conventional structural sections are claimed. The material for the tubing is standard ASTM A7 and A36 structural carbon steel.



Square sizes range from one to eight inches; rectangular sections, from 3×2 to 6×4 in. Surface finishes are as-rolled, oil-coated, galvanized, grit-blasted, and prime coated. **51**

ROSIN-CORE SOLDER — A rosin-core solder that is said to provide greater flow and reliability of solder connections is announced by **Alpha Metals Inc., Dept. S/A, 56 Water St., Jersey City 4, N.J.** The solder consists of a solder wire center core coated with flux, then covered with

FOR "BIRDS" OR BOXCARS



APPROX. ACTUAL SIZE

New PACIFIC "G" SENSING INERTIA SWITCH

...provides high performance ...reliable acceleration switching!

Pacific's new inertia switch is readily adaptable to meet a variety of "G" sensing uses from missiles to freight cars. It permits a wide variation in performance and range with only a minimum of engineering and development to meet specific requirements. A unique switching action provides positive "make or break" action of the electrical contacts at the "G" setting regardless of environmental conditions.

For information on Pacific inertia switch designed to your own requirements...or on a standard unit, WRITE TODAY. The engineering skill and creative ability of Pacific Scientific are at your service.

Write for current engineering data sheets—

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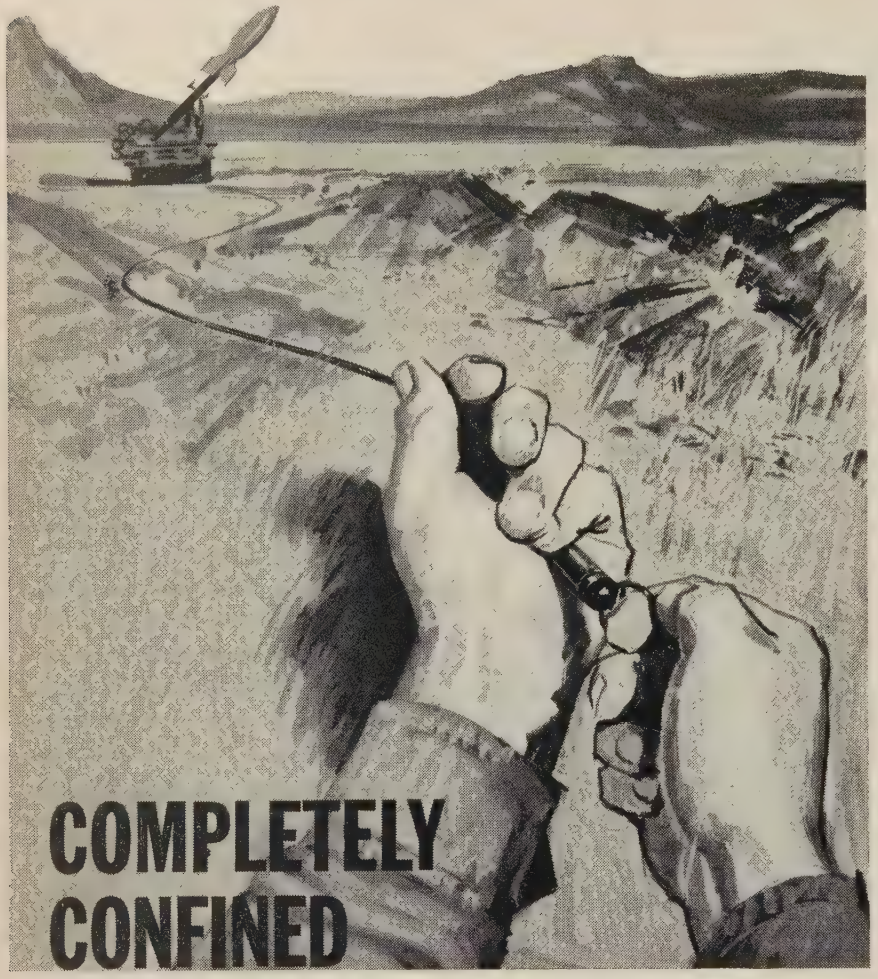
No. 82 on Reader Service Card

Ask your **Du Pont Explosive Systems Specialist** *about:*



MILD DETONATING FUSE

Protection against RF energy

This new and unique ordnance device enables you to transmit a uniform, high-velocity detonation for unlimited distances—*with essentially no risk of damage to adjacent components.*

You can get Du Pont Completely Confined Mild Detonating Fuse (MDF) in a variety of explosive trains, encased in concentric sheaths of metal, plastic, and fiberglas. It is far more insensitive to physical shock and RF energy than conventional electric systems, but can be easily fired non-electrically.

The protective jacket shields it against stray electrical currents such as those emitted by radar, radio transmitters or other high energy generators. Thus, Completely Confined MDF protects against premature detonation.

Also, non-electrical firing does away with the need for a source of EMF, enabling you to save weight by eliminating batteries.

Now obtainable with a core load of 2 grains/ft. of either PETN or RDX and a detonation velocity of 6,500-7,000 meters/second, Completely Confined MDF offers you a fast, reliable impulse transmission medium.

A Du Pont Explosive Systems Specialist is available to help you with your ordnance design problems. Just write E. I. du Pont de Nemours & Co. (Inc.), 2446 Nemours Building, Wilmington 98, Delaware.

DU PONT REG. U. S. PAT. OFF. **WEAPON SYSTEMS SPECIALTIES**

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

an outer sleeve of solder. It is available in all alloys of tin-lead and may be had in tin-lead-silver for soldering silver-fired ceramic parts. It is supplied in diameters from 0.032 in. up, and in varying flux percentages. The solder meets Federal Specification QQ-S-571C.

No. 267 on Reader Service Card

WELDING LATH – A combination tool for peripheral welding of rocket cases and turning and cut-off operations is announced by **The Standard Electrical Tool Co., 3001 River Rd., Cincinnati 4, Ohio.** The assembly uses a motorized spindle and grinding wheel mounted on a compound feed and a 360 rotary table. For center positioning, the tooling is mounted on a vertical lift column. The assembly permits any movement, and allows the spindle to be replaced with a tool block and tools.

No. 268 on Reader Service Card

ELECTROCHEMICAL MACHINES —A new line of electrochemical machines which remove hard-to-machine metal at production rates has been developed by **The Cincinnati Milling Machine Co., Dept. S/A, Cincinnati 9, Ohio.** The machines contain an antifriction bearing for the quill, a plexiglass enclosed work area, and an electrolyte reservoir tank and pump unit. Power supplies for the process operate between 1.5 volts and 24 volts dc and are equipped with automatic voltage or current stabilization.

No. 269 on Reader Service Card

SILICONE COATING – A process of applying a thin coating of silicon fluid to metals prior to heat treatment, to inhibit scaling, has been patented by **The Boeing Co., Dept. S/A, Seattle 24, Wash.** Total metal loss from three annealings is held to 0.4 to 0.6 mils, with only one descaling operation required. The coating reduces pickling time and retards intergranular attack on sensitive alloys. The process coating is Dow Corning 200 fluid at a viscosity of 50 cenistokes.

No. 270 on Reader Service Card

STEEL STUDS—Double drawn and heat-treated alloy steel studs, in lengths to 12 in., are available from **Jergens Tool Specialty Co., Dept. S/A, 712 E. 163rd St., Cleveland 10, Ohio.** Designed to prevent thread distortion and stud failure, the studs are said to result in substantial savings in materials, man-hours and machine shut-down time. With tensile strength of more than 125,000 psi, they are used principally in tool and die work for machine and fixture set-up. The studs are available in diameters from ¼ to 1 in.

No. 271 on Reader Service Card

No. 83 on Reader Service Card

No. 164 on Reader Service Card

EPOXY RESINS—Two new epoxy resins are available for filament winding systems requiring high tensile elongation and good handling characteristics. Developed by **Union Carbide Plastics Co., Dept. S/A, 270 Park Ave., New York 17, N. Y.**, they are designated Bakelite ERL-2256 and Bakelite ERL-2258. ERL-2256 has a viscosity range of 500-900 cps at room temperature, and ERL-2258 has a range of 100-500 cps at 25 deg C. At 160 deg F, the ERL-2256 system displays a flexural strength of 78,300 psi. ERL-2256 and ERL-2258 are currently being evaluated for several missile applications, such as motor casings, nose cones and space hardware.

No. 272 on Reader Service Card

WELDING TOOL—A pressure-sensing pencil probe type welding handpiece, designated VTA-43, designed by **Hughes Aircraft Co., Dept. S/A, 2020 Short St., Oceanside, Calif.**, facilitates small, pin-point welds from one side of a work surface. The VTA-43 includes both a pressure sensing weld probe and a ground probe. The probe is adjustable to fire the weld energy at preset pressures ranging from ½ to 5 lb., permitting welds on thin metals such as those in high density electronic component assembly. The unit weighs six oz without cables.

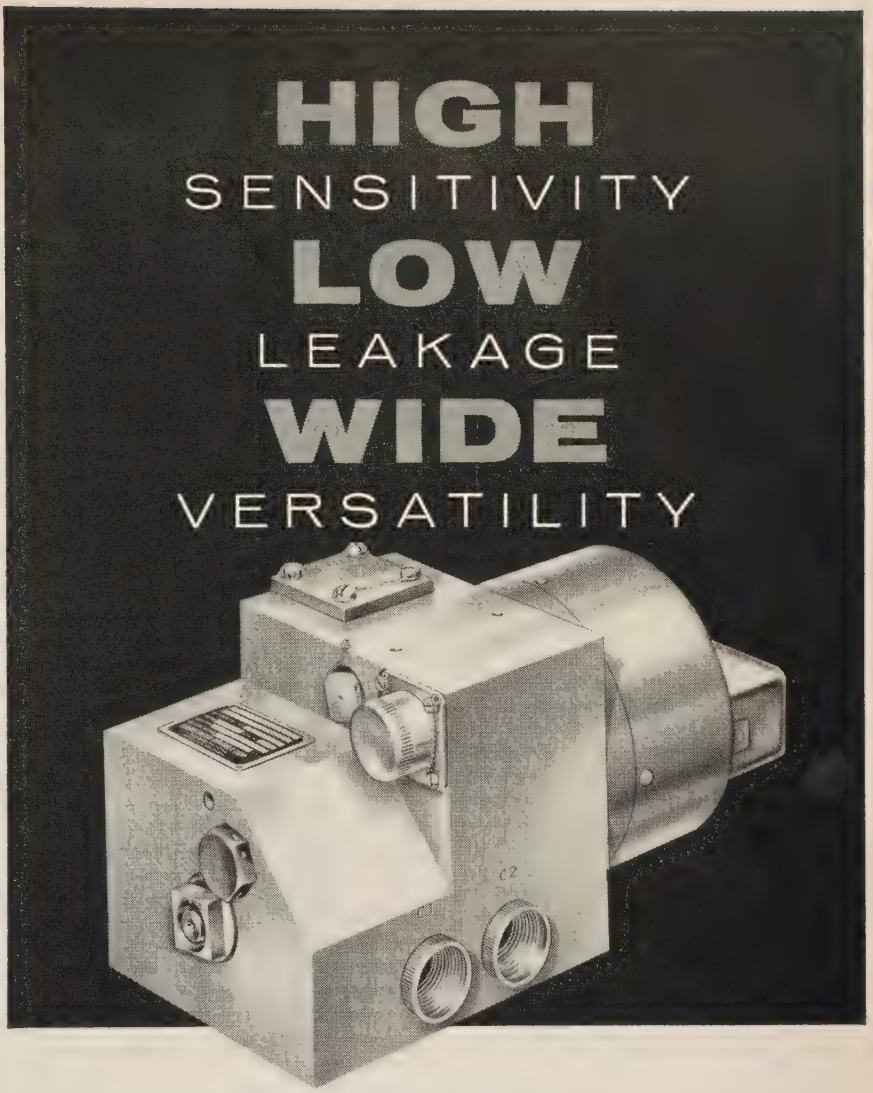
No. 273 on Reader Service Card

GROOVE DIAMETER GAGES — A series of dial indicating groove diameter gages for checking out-of-round conditions, recesses in blind holes and inside spherical radii has been developed by **Boice Gages, Inc., Dept. S/A, Hyde Park, N.Y.** The gages are said to be fast acting and are self-centering. Several models are available, for measuring a total range of inside diameters from 0.157 to 4⅞ in. Dial indicators graduated to 0.0001 in. or 0.0005 in. are standard. Modifications of the standard gages can be furnished for special groove gaging applications.

No. 274 on Reader Service Card

TURNING MACHINE — Precise contouring of nose cones up to 30 inches in dia. with an accuracy of ±150 μinch is possible on the vertical turning machine announced by **Frauenthal Div., The Kaydon Engineering Corp., Dept. S/A, Muskegon, Mich.** The Model 921 machine is equipped with a dual axis electro-hydraulic tracer system. This unit has a transistorized electronic control to guide both vertical and horizontal travel simultaneously through 360 deg. of motion.

No. 275 on Reader Service Card



New electro-hydraulic flow control servo valve for industrial, aircraft and missile ground systems

This new line of electro-hydraulic servo valves combines wide versatility with exceptional performance factors for industrial as well as aircraft and missile ground systems.

It features high sensitivity and low leakage. The highly-sensitive spool-type pilot stage valve provides control with input signal power as low as two milliwatts. Application of dither to pilot stage reduces threshold level for use in the most exact systems. Mechanical feedback system balances hydraulic controlling mechanism at position indicated by input signal.

The versatility of this valve permits easy modification for output flows from 1 to 20 gpm at 1000 psi pressure drop. Special models available with flow ratings up to 50 gpm. Rated for system pressures up to 3000 psi, the valve will function with pressures as low as 500 psi with only loss in dynamic response. For complete application information, write or telephone Mr. Lee Wixsom, 750 South Isis Avenue, Inglewood, Calif., Phone — ORchard 1-7589, DDD Code 213.

PERFORMANCE FEATURES OF TYPE 141VN8 SERVO VALVES

Pressure rating: 3000 psi operating, 4500 psi proff, 7500 psi burst
Port Connections: AND10050
Internal leakage at null: 25 cu. in./min. max.
Output flow: shaped or linear
Rated flows: to 20 gpm at 1000 psi drop
Ambient and media temperature limits: −65 F to 275 F and higher

CONSOLIDATED CONTROLS CORPORATION

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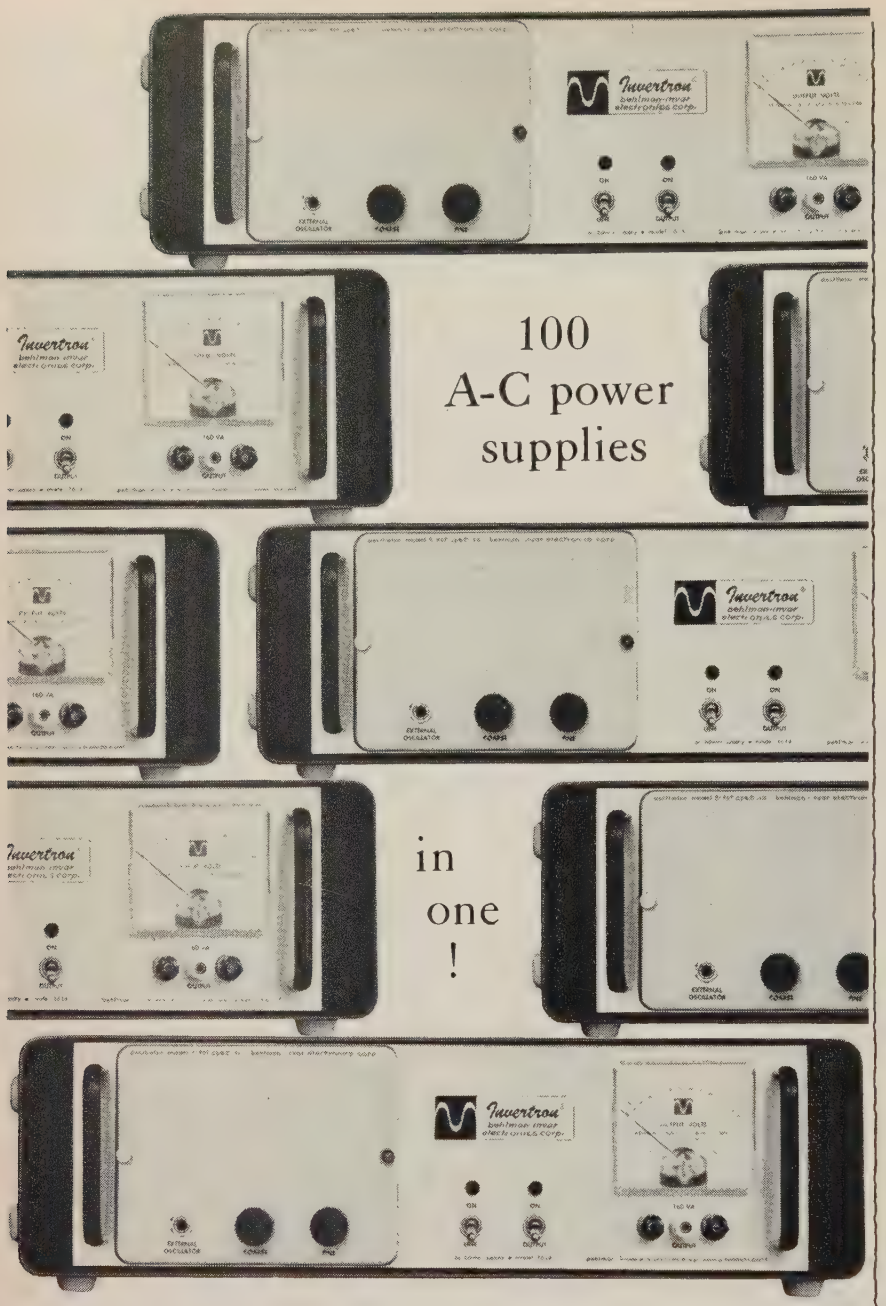


Never before has there been an a-c power source as flexible as the Behlman-Invar 161A Invertron. The unit features a wide variety of separate plug-in oscillators in both fixed and variable frequencies from 45 to 5000 cps. Finally, the electronic industry's need for a low-cost, general purpose a-c power supply has been realized.

The 161A is so flexible, in fact, that three of the units can be stacked. The three outputs can then be connected in a Y configuration, employing a 3-phase plug-in oscillator, to give 3-phase output at approximately 500 volt amperes.

The 161A is available either rack mounted or for bench use, and is only 5¼ inches high, 17 inches wide and 16 inches deep. Additional features include: extended frequency capability, excellent short term voltage amplitude stability and zero response time. The price is only $420.00 f.o.b. Santa Monica, California. Prices on a variety of plug-in oscillators are available on request.

Behlman-Invar also manufactures a broad line of both a-c and d-c laboratory power supplies as well as modular power supplies for rack mounting. Modules may be operated in series or in parallel for maximum output and flexibility of operation.

BEHLMAN-INVAR ELECTRONICS CORP.

1723 CLOVERFIELD BOULEVARD • SANTA MONICA, CALIFORNIA

Behlman-Invar representatives are: T. Louis Snitzer Company—Los Angeles, La Jolla and Sunnyvale, California. • Cain and Company—Albuquerque; Great Neck, N.Y.; Boston; Orlando, Fla.; Philadelphia; Chicago; Dallas; Washington, D.C.

COLUMBIUM ALLOY —The availability of a high-strength columbium-base alloy containing tungsten and zirconium has been announced by **Haynes Stellite Co., Dept. S/A, 270 Park Ave., New York 17, N. Y.** The alloy can be fabricated by conventional methods, including welding, and has an ultimate strength of over 25,000 psi at a temperature of 2400 deg. F. According to the company, tests carried out on the alloy during its development showed it to be one of the strongest materials of its type at temperatures above 2000 deg. F.

No. 276 on Reader Service Card

COATING—A flame and heat resistant coating, designated "Pyroshield 21," is capable of withstanding temperatures to 4000 deg F. The material, developed by **Columbia Technical Corp., Dept. S/A, 24-30 Brooklyn-Queens Expressway West, Woodside 77, N. Y.,** is not flammable in its liquid or dried form. A 50-mil thick coating measures 255 deg F on the protected surface after exposure to a temperature of 2100 deg F for five min.

No. 277 on Reader Service Card

DATA FILE

ALLOY BRAZING—A brazing alloy reference chart, listing metal compositions, density, and melt and flow temperatures for silver brazing alloys has been published by **Engelhard Industries, Inc., Dept. S/A, 75 Austin St., Newark 2, N.J.** The chart details 37 compositions, including all commercially important silver base alloys and many special purpose compositions.

No. 278 on Reader Service Card

DAMPED LAMINATES — A new 8-page bulletin describing damped laminates for control of structural resonant response has been published by **Lord Mfg. Co., Dept. S/A, Erie, Pa.** Specific examples of applications in the aircraft, missile and electronics fields are illustrated.

No. 279 on Reader Service Card

DAP MONOMER—A 16-page booklet describing the use of diallyl phtalate monomer in polyester resin systems is offered by **Food Machinery & Chemical Corp., Dept. S/A, 161 E. 42 St., New York 17, N.Y.** The bulletin is illustrated with a detailed table and charts on properties and performance.

No. 280 on Reader Service Card

No. 85 on Reader Service Card

GRAPHITAR®

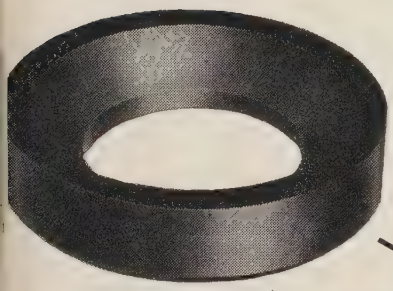
(CARBON-GRAPHITE)

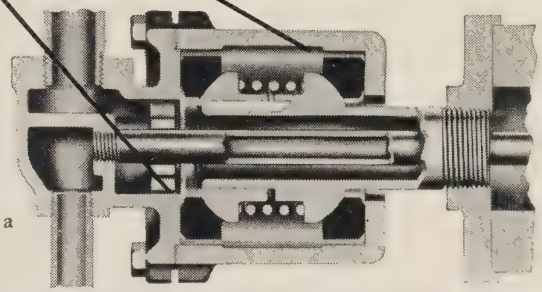
FOR PERFORMANCE

Superior performance and unusually long service life, even in tough applications, is practically second nature to parts made of GRAPHITAR. That's because they combine GRAPHITAR's chemical stability, heat resistance, low coefficient of friction, adaptability to self-lubrication, mechanical strength, hardness and light weight. An everyday application of GRAPHITAR that illustrates well its versatility and remarkable performance can be found in the face-type valves employed in bulk station gasoline meters. These valves incorporate GRAPHITAR seats.

Here, GRAPHITAR's corrosion resistance, chemical inertness and resistance to expansion or contraction under rapid temperature changes, allow the valves to provide a leak-tight seal with excellent wear characteristics. These same characteristics are necessary for good performance wherever steam, gas and chemicals must be handled under the most adverse conditions. Perhaps your product can benefit from the top performance of GRAPHITAR, a unique and versatile engineering material.

R-302-1





lf-aligning seals of RAPHITAR are em-oyed in rotary pressure ints handling steam, tter, hot oil, trichlor-hylene, powdered talc and a riety of chemicals.

Comparative testing of various grades of GRAPHITAR self-aligning seals is accomplished on this equipment, which duplicates actual operating conditions. GRAPHITAR rotary pressure joint seals such as these often operate at 400 psi, at 650°F. and at rotary speeds of 600 ft/min.

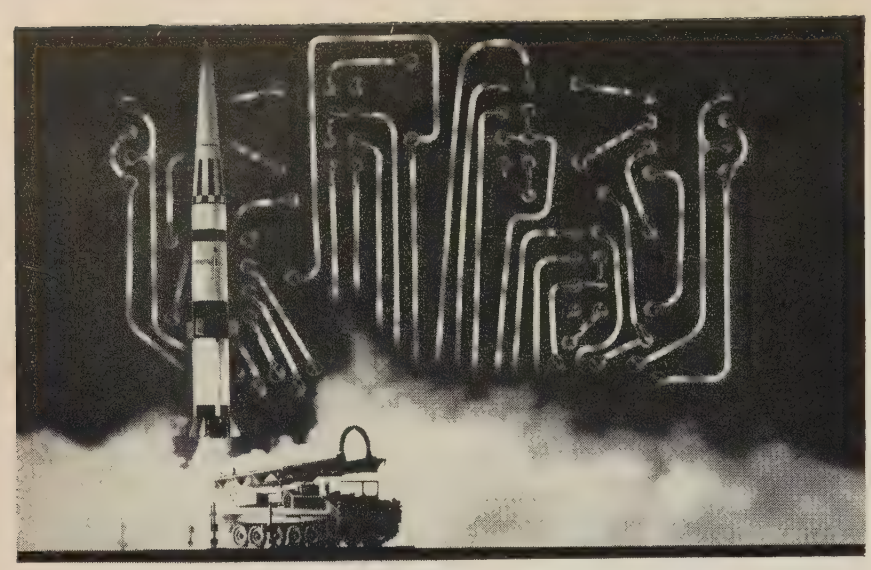
GRAPHITAR is a material uniquely designed by its nature for solving tough problems and improving processing, and it can be further custom-engineered to meet your exact specifications. For complete information on GRAPHITAR . . . send for Engineering Bulletin #20.

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION, SAGINAW 13, MICHIGAN

GRAPHITAR® CARBON-GRAPHITE • GRAMIX® POWDER METALLURGY • MEXICAN® GRAPHITE PRODUCTS • USG® BRUSHES

No. 86 on Reader Service Card



AUTRONEX ACID GOLD* MEETS PERSHING MISSILE SPECS

Dev Tek, Inc., Orlando, Florida, uses the patented Autronex Acid Gold Process to plate circuit conductors, as applied to the new Pershing Missile. According to Mr. A. F. Goldsby, Dev Tek President, Autronex Acid Gold affords easy compliance with the rigid ABMA-428 specifications for a hard, bright coating of gold alloy 100-150 millionths thick covering all circuit conductors. Pershing Missile component-finishing specifications are acknowledged to be among the most exacting. Whenever tough specifications are to be met, whenever the unique properties of precious metals are required *without the shortcomings of conventional electroplate,* missile, electronics manufacturers and government agencies specify Sel-Rex. Technical literature free on request. Specify precious metal and your application

Sel-Rex® *Patented

SEL-REX CORPORATION
NUTLEY 10, NEW JERSEY
The World's Largest Selling Precious Metal Plating Processes

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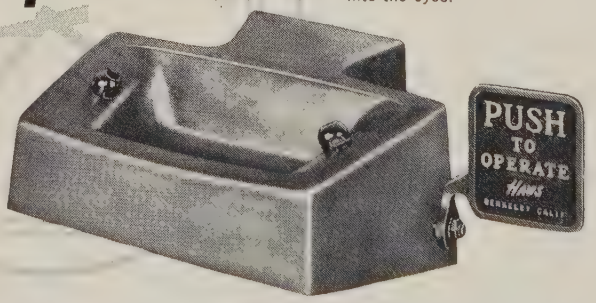
SPLIT SECOND SAFETY

Model 7300
Cast aluminum receptor; twin fountain heads direct automatically regulated streams into the eyes.



EMERGENCY EYE-WASH

Sensitive eye tissue can be destroyed in moments. Contamination from industrial caustics and chemicals requires instant first aid . . . and a HAWS Emergency Eye-Wash Fountain can mean the difference between temporary irritation and permanent injury! Write for your free HAWS catalog.

Since 1909 HAWS **EYE-WASH FOUNTAINS**

a product of HAWS DRINKING FAUCET COMPANY 1443 Fourth St., Berkeley 10, Calif.

No. 88 on Reader Service Card

ALLOY CASTING—A 20-page catalog, G-261, describing high alloy casting service in the static, centrifugal and shell-molded categories is offered by **The Duraloy Co., Dept. S/A, Scottdale, Pa.** It lists the ACI nomenclature, metallurgical properties, and uses of 55 different alloys for the chemical and metal treating industries.

No. 281 on Reader Service Card

ELECTRON BEAM FURNACE—A four-page brochure describing electron beam furnaces with ratings from 40 to 150 kiv is available from **Stauffer Metals Div., Dept. S/A, 1201 S. 47th St., Richmond 4, Calif.** In addition, a line of refractory metals and alloys and engineering services are outlined.

No. 282 on Reader Service Card

GREASE — A 32-page booklet summarizing the basic principles, properties, and application of lubricating grease is available from **Bardahl Mfg. Corp., Dept. S/A, 1400 N.W. 52nd St., Seattle 7, Wash.** Properties and testing methods of grease are presented.

No. 283 on Reader Service Card

ALLOY TUBING—A 20-page catalog, Bulletin 13, setting forth sizes, specifications, finishes and suitable applications of small diameter tubing, is available from **J. Bishop & Co., Dept. S/A, Malvern, Pa.** A complete section is devoted to inspection procedures and quality control.

No. 284 on Reader Service Card

FACILITY—A brochure describing facilities for handling and cleaning of LOX and fluid systems has been published by **Stellardyne Laboratories, Inc., Dept. S/A, 7739 Cuyamaca St., El Cajon, Calif.** Information is presented on procedures of inspection assembly, cleaning and testing.

No. 285 on Reader Service Card

WELDING—A 12-page brochure describing "Versa-Welding", a reliable method of joining materials, has been published by **Cleveland Pneumatic Tool Co., Dept. S/A, 3781 E. 77th St., Cleveland 5, Ohio.** The brochure also presents application data on flash butt and pressure welding.

No. 286 on Reader Service Card

ALUMINUM CASTINGS—Application data pertinent to investment casting of aluminum alloys are described in a brochure from **Misco Precision Casting Co., Dept. S/A, 126 Gibbs St., Whitehall, Mich.** Parts fabricated of 356 aluminum alloys are detailed.

No. 287 on Reader Service Card

MOLDED RUBBER — Bulletin SR-59 describing standard and custom-molded rubber parts are offered by **The Stalwart Rubber Co., Dept. S/A, Bedford, Ohio.** The brochure discusses manufacturing capabilities with several types of rubber.

No. 288 on Reader Service Card

METAL CONTACT—A line of products designed to improve electrical contact is detailed in a bulletin from **Caig Laboratories, Inc., Dept. S/A, 46 Stanwood Rd., New Hyde Park, N.Y.** The bulletin discusses contact reliability and offers specifications covering the products presented.

No. 289 on Reader Service Card

ASBESTOS PLASTIC—A high-temperature asbestos-base reinforced plastic developed for rocket applications is described in Bulletin 8.5 published by **Taylor Fibre Co., Dept. S/A, Norristown, Pa.** Sizes are given for the various forms in which "Tayloron Pa" is supplied.

No. 290 on Reader Service Card

HEX HEAD SCREWS—The advantages and design factors of hex head fastener use are discussed in a booklet from **The Cleveland Cap Screw Co., 4400 Lee Rd., Cleveland 28, Ohio.** The booklet discusses ASA standards pertaining to hex head fasteners.

No. 291 on Reader Service Card

LIGHT METALS—Data and specifications covering aluminum, titanium, and magnesium are detailed in a brochure published by **Brooks & Perkins, Inc., 1950 W. Fort St., Detroit 16, Mich.** The brochure offers design information on material selection, as well as application data.

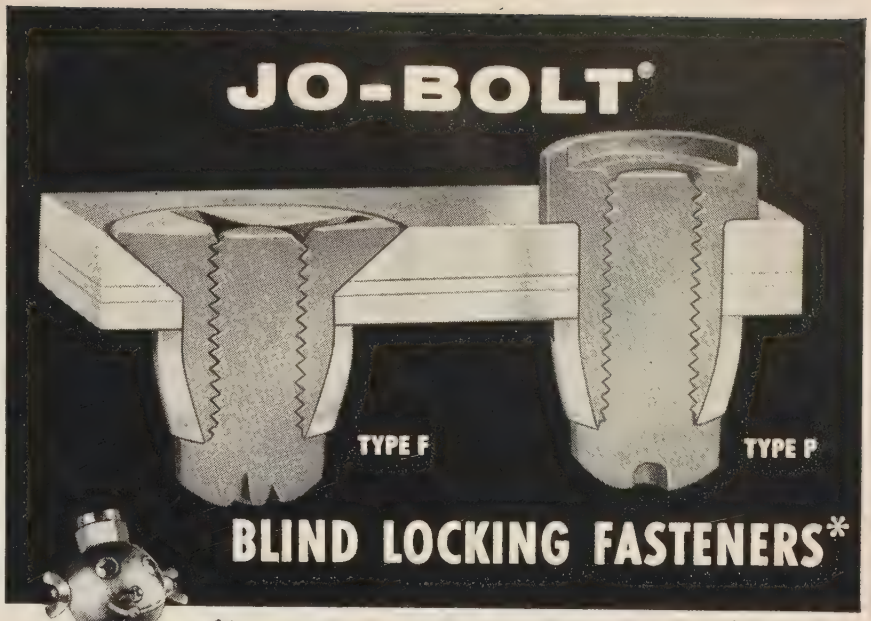
No. 292 on Reader Service Card

INSULATION — Silicone rubber wire and cable insulation for aircraft and missile support equipment is the subject of a data sheet issued by **General Electric Co., Dept. S/A, Waterford, N.Y.** The radiation resistance of polymers is shown in chart form. Physical and electrical properties are discussed.

No. 293 on Reader Service Card

WELDING—An arc-welding system that is capable of providing wire speeds to 1170 inches per min. is offered by **Westinghouse Electric Corp., Dept. S/A, Buffalo 5, N.Y.** The SA-200 welding system will accommodate wire sizes in mild steel or stainless steel from 0.025 to 0.047 in.

No. 294 on Reader Service Card



* Patented

DO IT BETTER · DO IT FASTER in missile/aircraft frame assembly

What happens in JO-BOLT Fastener installations can be seen at a glance, in the cross section above. The resulting clamp-up of sheets and structural members is tight and positive, 100% effective.

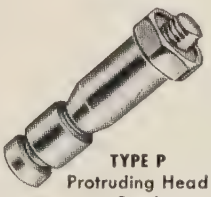
That's highly important . . . but not even the half of it. First, consider this . . . JO-BOLTS® are high-strength structural fasteners, typically providing: shear strength of 95,000 psi min. in steel types; 85% AN Bolt tensile strength in #10 and ¼" diameters; vibration resistance superior to bolts with lock nuts.

Second, JO-BOLT Fasteners are lightweight and compact, allow savings in fastener weights averaging 50% or higher, often permit use of narrower and lighter substructures.

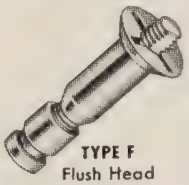
Third, JO-BOLT Fasteners can always be installed by one man from one side of the work . . . eliminating most common access and clearance problems.

Finally, JO-BOLT Fasteners are foolproof and fast, can be popped into holes prepared and aligned for them, and driven to grip inside of seconds, always resulting in high-quality work, uniform and unmarred, regardless of worker skill.

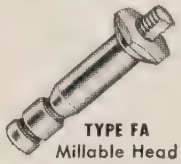
They are so good, in fact, at fastening better and faster that they've been preferred and specified in practically all high-performance aircraft ever since introduction.



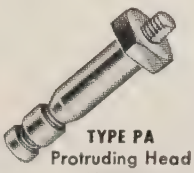
TYPE P
Protruding Head
Steel



TYPE F
Flush Head



TYPE FA
Millable Head



TYPE PA
Protruding Head
Aluminum

Write for illustrated booklet J 59. It lists specifications for all types, tells about A 286 Hi-Temp and other special JO-BOLT Fasteners.

National

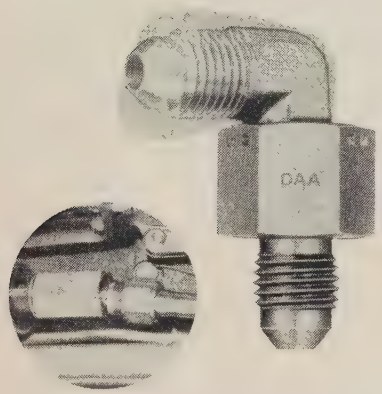
THE NATIONAL SCREW & MFG. COMPANY
CLEVELAND 4, OHIO
California Division, Los Angeles 22

No. 89 on Reader Service Card

DESIGN DEVELOPMENTS

For more details on the equipment, processes, and facilities described in this section,

SWIVEL FITTINGS FOR RIGID METAL TUBING



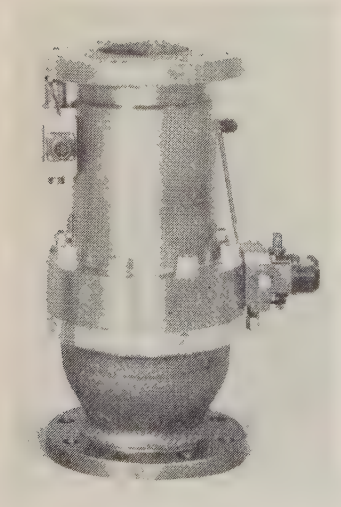
Self-aligning swivel fittings that make possible the reliable use of rigid metal hydraulic tubing in aircraft and missiles has been developed by Dumont Engineering Co., 1401 Freeman Ave., Long Beach 4, Calif. As a rule, rigid metal tubing formerly was considered impractical, says the company, because system impulse pressures, vibration characteristics, and thermal shock required more flexibility than the tubing could provide.

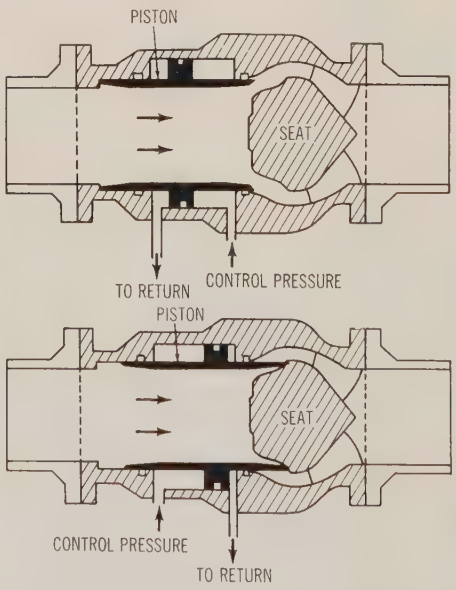
The new Dumont fittings are being used in the hydraulic system of the NAA Hound Dog missile, They can rotate through 360 deg and compensate for mis-alignment up to 14 deg, absorbing vibration, shock, and thermal expansion in fluid lines and reducing the possibilities of tubing flare breakage or connector nut loosening.

The self-aligning feature can also be used to advantage in tubing system assembly to precisely align with the tubing flare, so that there will be no "built-in" stresses in the tubing. The fittings operate at a relatively low torque. **55**

Versatile Valve Has Minimum Pressure Drop

by A. A. Meddock, Hydraulic Engineering, Bendix-Pacific Div., The Bendix Corp., North Hollywood, Calif



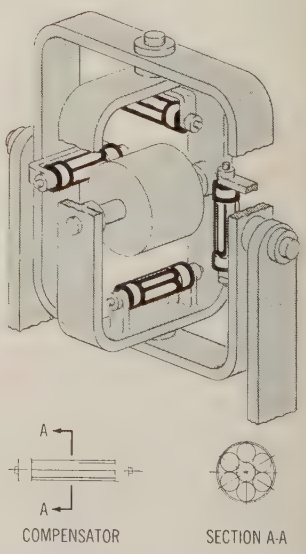


With only one moving part, this field-qualified "fluidal" valve can handle a wide variety of fluids, using any of several methods of actuation. It provides a minimum pressure drop and quick, accurate response.

Produced in sizes from ¼ to 24 in., the valve has handled oil, gas, and chemicals systems operating from 25 to 12,000 psi at temperatures from —65 to 400 deg F.

Shutoff is bubble-tight. Because of its low hysteresis, the valve is ideal for precise fluid blending. Piston position, indicated mechanically, serves as feedback information in closed loop systems. **57**

Gyros Balanced by Electric Induction



A mass-compensating system to keep gyroscopes in precise balance by electric induction of compensating torque has been developed by Avcon Corp., Scarsdale, N.Y. The "mass shift compensator" is essentially an electrolytic cell with two equal masses of metal at opposite ends of a glass cylinder filled with an electrolyte. Powered by direct current, metal plates from

Propulsion and Accessory Equipment

write in item numbers on Reader Service Card

one electrode to the other, changing the relative electrode masses and so producing a torque on the gyroscope gimbal. The direction of plating can be varied, depending on the polarity of the current.

The unit can supply a compensating torque of 10^{-6} gm-cm/sec up to a total of 0.030 gm-cm. The power required by the system is less than one milliwatt. The compensator measures 1 9/16 in. in length and 0.25 in. in diameter.

The compensator is said to overcome the problem of mass shift and precession due to gyro fabrication and assembly deviations. In addition, the company says it reduces the delays in operations like missile launchings when gyro drift is discovered, since the error now can be readily eliminated. **59**

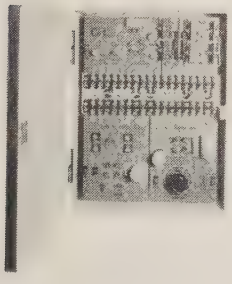
Proportional-Power Amplifier for Electric Control

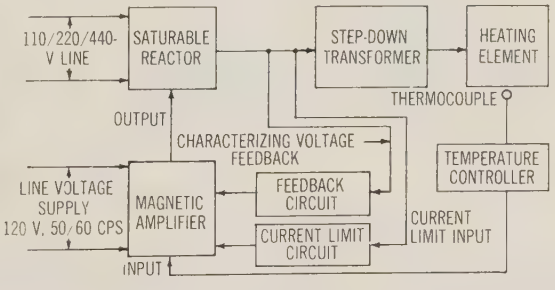
A modular proportional-power magnetic amplifier providing accurate electric control has been developed by Hevi-Duty Electric Co., 304 Hart St., Watertown, Wis. Using a saturable reactor, it produces a percentage change in process power for a linear change in the system input.

The Type 300 amplifier operates from a 100-V, single-phase, 60-cycle line with zero to five milliamperes input. The output is variable from zero to 85-V DC.

The 300 precisely controls any electric or mechanical process for which a proportional power curve is required. In a glass-melting furnace installation, it controlled the 1400-deg C furnace temperature to within 0.1 deg C for over a year.

The system is said to eliminate the need for readjustment of proportional band settings, rate time, and reset rate when processing temperatures and feed rates are changed. A built-in current limiting circuit changes the control circuit characteristics so that power to heating elements may be limited from a maximum of 50 to 100 per cent of the reactor rating. **56**





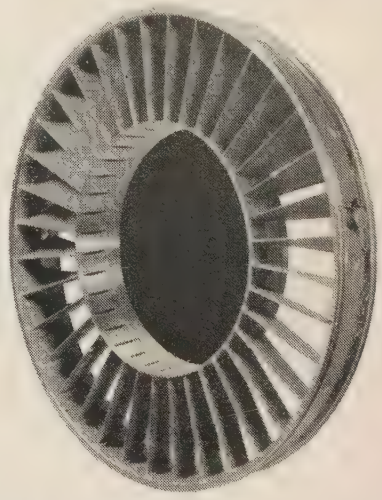
DC MOTORS—A series of brushless dc motors, designated Model T, using solid-state commutation, has been developed by **Brailsford & Co., Dept. S/A, 670 Milton Rd., Rye, N. Y.** Nominal shaft speed is 3000 rpm, power inputs range from 300 mw to 4 watts. Input voltages of 12 and 28 volts dc are standard. Without gear head, the motor measures 1½ x1½ x 1¾ in. and weighs 4.5 oz.

No. 295 on Reader Service Card

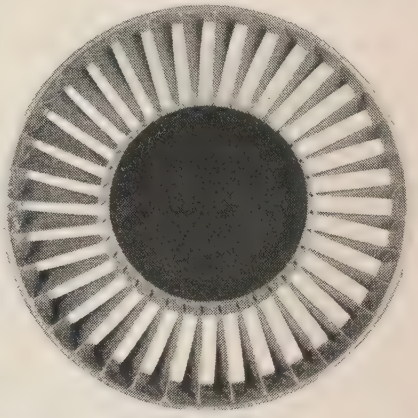
SLEEVE-BEARINGS—A line of self-lubricating bearings has been announced by **Carter Mfg. Co., Dept. S/A, Ferrysburg, Mich.** An outer sleeve in which grooves are machined provides an oil reservoir. Bore diameters range from 0.125 to 1.375 in., rpm ratings are from 2500 to 6000 rpm. The outer housing is cold rolled steel, inner sleeve material is sintered bronze.

No. 296 on Reader Service Card

STALKER



FABRICATIONS



feature lower first cost – increased payloads

The Stalker Corporation has proved to the aviation industry that Stalker super alloy sheet metal fabrications for gas turbine assemblies *are not only lower in first cost but lighter in weight* than machined components, which permits the carrying of heavier payloads.

The precision which is demanded by both aviation and nuclear equipment industries is insured through use of Stalker's exclusive ORTHOBRAZE fabrication methods.

Stalker services include product development, engineering, manufacturing, test facilities — U.S.A.F. approval No. MIL-Q-5923C.

Photographs courtesy of Lycoming Division, Avco Corp.

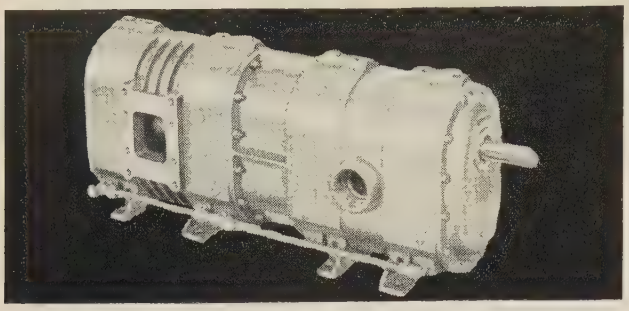
THE STALKER CORPORATION

Phone: Bay City Twinbrook 3-7562

905 Woodside Ave.
Essexville, Michigan

No. 90 on Reader Service Card

Guaranteed Oil-free Compressed Air



With M-D Blowers

When a customer required 62 CFM of absolutely oil-free air at 35 PSIG for a missile cooler they selected the M-D model—380. M-D design eliminates the possibility of oil contamination. Other M-D features include positive displacement with no surge or vibration; compactness as a result of the unique 3-lobe rotor design; quiet operation and the reliability inherent in a simple rotating mechanism with no internal contact surfaces. Added to all these is the fact that M-D Blowers cost less than you think.
Write for complete information today.

M-D BLOWERS, INC., RACINE, WISCONSIN
A Subsidiary of Miehle-Goss-Dexter, Inc.

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THOROUGHBRED QUALITY

WORKHORSE CAPACITY

GENISCO'S RATE-OF-TURN TABLE *Model C181*

Genisco Rate-of-Turn Table, Model C181, is a thoroughbred performer in the precision work of calibrating and evaluating rate gyroscopes. Speed is infinitely variable from .01 to 1200 degrees per second, with accuracy of 0.1% of setting. In addition, Model C181 is unusually rugged for continuous use over long periods of time, with minimum maintenance. Simple to operate, with excellent repeatability, and versatile mounting facilities, it is ideal for large-volume production-line testing. May also be used as a very precise, practically vibrationless centrifuge for low-G-force testing and calibrating purposes. Numerous accessories increase versatility of the C181. Write today:

Genisco INCORPORATED

2233 FEDERAL AVE., LOS ANGELES 64, CALIF.

No. 92 on Reader Service Card

Propulsion and Accessory Equipment

PNEUMATIC TRANSMITTER – A pneumatic transmitter, designated Model 273, offers differential pressure spans from 0 to 400 psi, and working pressures rated to 10,000 psi. It is highly compact, weighing less than one-half the weight of other pneumatic transmitters, according to **Barton Instrument Corp., Dept. S/A, 580 Monterey Pass Rd., Monterey Park, Calif.** This transmitter employs the torque tube method of positive motion transmission which eliminates friction, leakage, and the need for lubrication. The unit is sensitive within 0.05 per cent differential pressure range. The operating span is continuously adjustable to 20 per cent of standard differential pressure range of the meter body.

No. 297 on Reader Service Card

CONTROL SWITCH – A multi-speed rpm control switch measuring 1¾ x 2½ in. square, and weighing 15 oz has been announced by **Kahn and Co., Inc., Dept. S/A, P. O. Box 516, Hartford 1, Conn.** Units are available with 1, 2 or 3 snap-action electrical switches, each set to actuate at a preset rpm. Repeatability and differential are 1 per cent or less. Operating ranges between 700 and 5000 rpm are obtainable. The speed control switches have been qualified to applicable military specifications for environmental conditions.

No. 298 on Reader Service Card

VANEAXIAL BLOWER – A new vaneaxial blower, VAX-2-MM, 2 in. in diam., delivers 37 cfm at 1.5 in. water back pressure at 16,500 rpm using 26 volts d-c. The blower housing and propeller shroud, as well as the propeller, are black anodized aluminum castings, says **Globe Industries, Inc., Dept. S/A, 1784 Stanley Ave., Dayton 4, Ohio.** Radio noise filtering can be provided. Maximum current is 1.15 amp at free air delivery of 53 cfm.

No. 299 on Reader Service Card

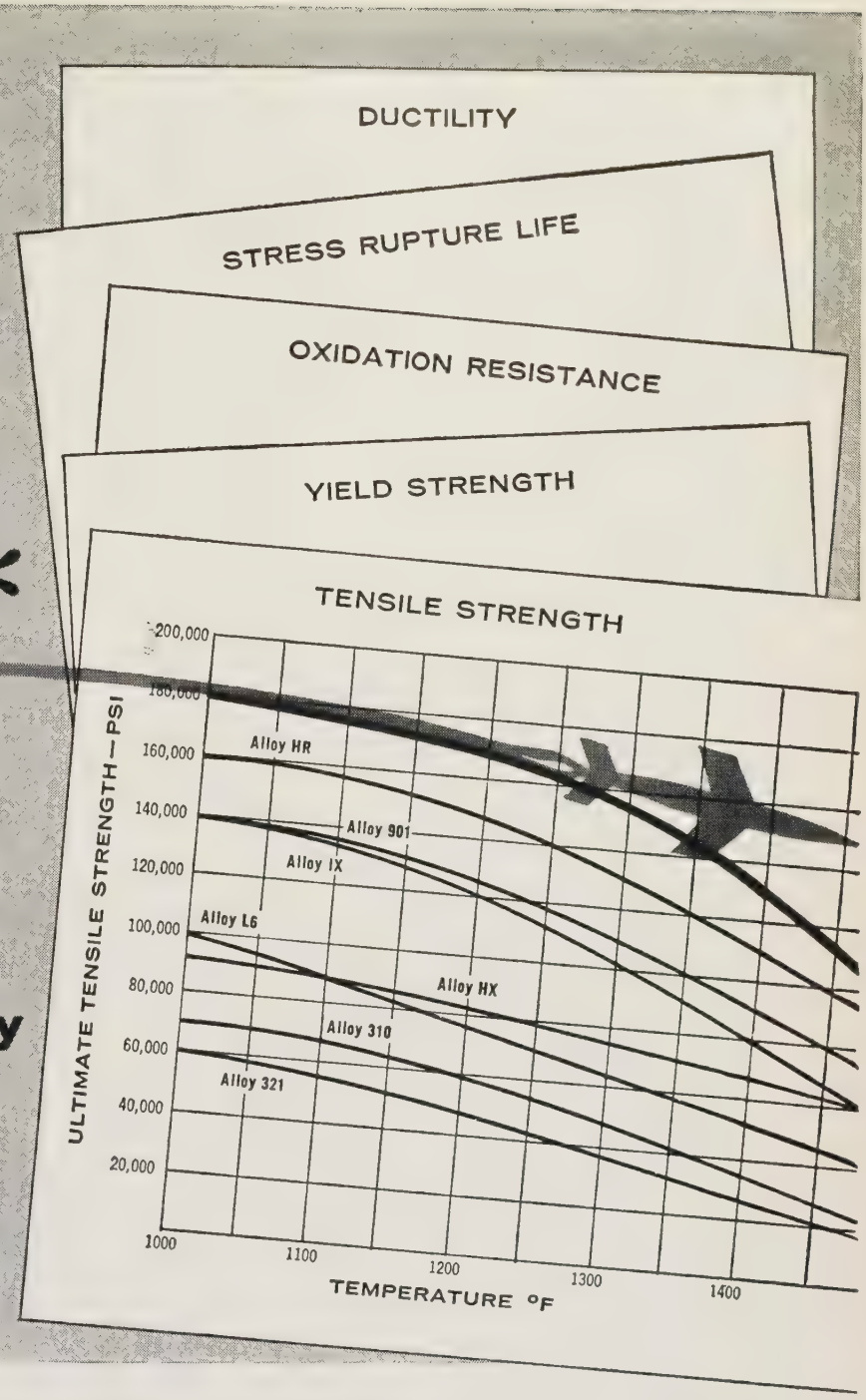
GEARMOTORS – A line of permanent magnet Type VS d-c gearmotors providing 35 oz-in. torque continuous duty have been announced by **Globe Industries, Inc., Dept. S/A, 1784 Stanley Ave., Dayton 4, Ohio.** An end-mounted reducer provides 62 ratios from 7.88:1 to 25,573:1 and a side-mounted reducer provides a choice of 27 ratios from 26.93:1 to 2511:1. The units are designed to meet applicable MIL, specs. The motor has 13 standard armatures for up to 50 volts dc; motor is rated at 0.0025 hp at 17,000 rpm.

No. 300 on Reader Service Card

HIGH on every chart:

CM-R 41*

most dependable alloy in use today in the 1200°-1800°F range



In *all* ways, CM-R 41 is a remarkable alloy. No other high-temperature alloy used in production today equals its tensile strength. In other properties, too, CM-R 41 is far ahead of the field.

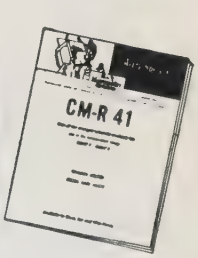
Also important, this nickel-base, vacuum-melted alloy is easy to work with. It's readily formable by drawing, bending, spinning — welds to similar or dissimilar materials.

Cannon-Muskegon offers CM-R 41 in standard 36″x96″ sheets .015″ to .125″ thick, in smaller sizes down to .010″, in bar stock up to 3″ in diameter . . . foil down to .001 in thickness . . . and fine wire only .0015 in diameter.

For complete details, write for Technical bulletin No. 86.

*Used on NASA-McDonnell Mercury Spacecraft.

ULTRAMET VACUUM ALLOYS



CANNON-MUSKEGON CORPORATION

2897 Lincoln Avenue • Muskegon, Michigan

METALLURGICAL SPECIALISTS

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In engineering and manufacturing AMF has ingenuity you can

He has a hand in planning for the men in the moon

He's one of a staff of AMF engineers who are solving space environment problems on a here-and-now basis.

He has plans for an orbital launch facility (picture, top left) to help them get there in the first place. Inside, in a shirt-sleeve environment (top, right), a space vehicle can be prepared for launch to the moon itself. On the moon (center), connected structures above and below the surface are required for the Advanced Habitation Engineering needed to support a permanent lunar base. Lunar traverser (bottom) is used to move men and materials and assist in construction of a permanent base.

Already, AMF has designs and concepts which make those pictured obsolete. As new knowledge becomes available, AMF quickly incorporates it into simpler, more reliable, more easily fabricated mechanisms.

AMF has completed and is now carrying on studies and feasibility investigations covering a wide range of space environment problems in conjunction with space vehicle manufacturers and for several government departments. Space environment, itself, is just one of a virtually complete spectrum of AMF defense capabilities.

For more information, write American Machine & Foundry Company, Government Products Group, AMF Building, 261 Madison Avenue, New York 16, N. Y.

AMF

AMERICAN MACHINE & FOUNDRY COMPANY

No. 94 on Reader Service Card

Propulsion and Accessory Equipment

CYLINDER VALVE — A new self-contained and self-regulating integral cylinder valve that operates without an outside power source or control system has been developed by **General Kinetics Corp., Dept, S/A, 197 So. Van Brunt St., Englewood, N.J.** It is suited for nuclear control and stop valves, flow control and pressure reducing and back pressure control. Highly resistant to abrasion and erosion, the "Hi-100" valve features straight-through, non-turbulent flow, and self-purging action characteristics. Due to its no-leakage, self-contained design, the valve is expected to find application in handling radioactive materials.

No. 301 on Reader Service Card

SYNCHROS — A line of pancake synchros and resolvers designed for direct mounting and installation in stable platforms and gyros has been developed by **Giannini Controls Corp., Dept. S/A, 1600 So. Mountain Ave., Duarte, Calif.** Featuring accuracies up to 5 min and high precision mechanical tolerances to maintain concentricity, the units feature narrow stack heights and large internal diameters. They are obtainable as rotor and stator assemblies or with custom flanges and hubs designed for specific customer requirements.

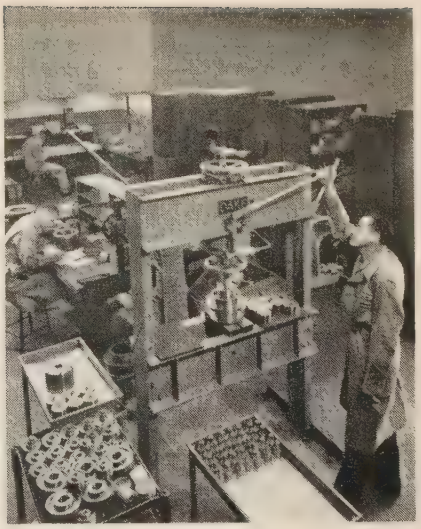
No. 302 on Reader Service Card

SQUIB-OPERATED DISCONNECT —A new squib-operated disconnect coupling designed for remote operation incorporates an internal fluid coupling qualified to MIL-C-25427. Designed by **Pyronetics, Dept. S/A, 11973 E. Slauson, Santa Fe Springs, Calif.**, the unit is equipped with ¼ in. standard flared tube fittings. It can be manually connected or disconnected. Modifications of the coupling are available for service in nitrogen gas as well as in a variety of fluids. Operating pressure rating is 4000 psi.

No. 303 on Reader Service Card

EXPLOSIVE CARTRIDGES — A family of explosive cartridges, designated PC-10, providing power to actuate mechanisms much as separation systems and thrust reversal and termination systems, has been developed by **Hi-Shear Corp., Dept. S/A, 2600 W. 247 St., Torrance, Calif.** The cartridges meet all pertinent military specifications and are environmentally qualified. A typical cartridge weighs 14 gm, produces 10,000 psi gas pressure in less than 5 msec. It functions with 99.8 per cent reliability at temperatures of −320 to +500 deg F and withstands 100 g shock loads.

No. 304 on Reader Service Card



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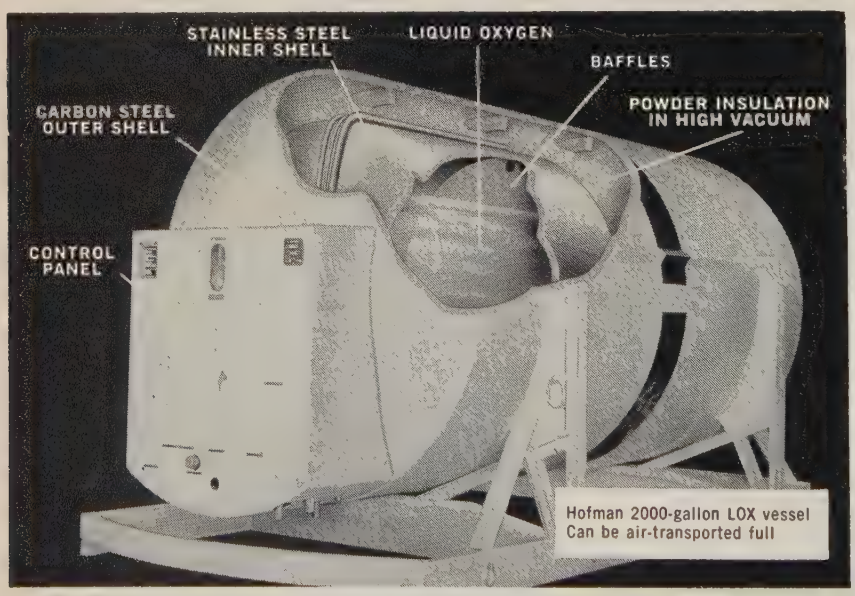

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No. 220 on Reader Service Card

LINEAR ACCELEROMETER—Series 31D linear accelerometers incorporating a new selftest circuit are now available from **Dynamic Measurements Co., Dept. S/A, 106 Terwood Rd., Willow Grove, Pa.** Throwing a remote switch applies a "standard" acceleration to the transducer, permitting absolute evaluation of operability up to the moment of flight. The selftest feature checks the response of all mechanical, hydraulic, and electronic systems which accept and respond to the output of the accelerometer. The units have full scale ranges from 0.1 g to 10 g, natural frequencies from 5 to 40 cps, and output voltages to 10 volts.

No. 305 on Reader Service Card

SERVO ACTUATOR—A servo unit that has actuator, servo valve, and position transducer integrated into a single compact system is being produced by **Hydraulic Research & Mfg. Co., Dept. S/A, 2835 N. Naomi St., Burbank, Calif.** The unit was designed originally for the first stage of a high production solid rocket engine. Application possibilities include testing for rocket nozzles, gimballing of small rocket engines, precision positioning. The actuator functions in systems to 3000 psi and has a piston velocity at 1000 lb load of 15 in. per sec. Modifications can be made for adjustment to specific requirements.

No. 306 on Reader Service Card

ROTARY SOLENOID—A new rotary solenoid requiring less input current than a transistor has been developed by **John Oster Mfg. Co., Avionic Div., Dept. S/A, Racine, Wisc.** The type 9931-04 requires 0.0033 amp input current at room temperature and 0.005 amp at 29 volts dc at −55 deg C. Voltage range is from 25 to 29 volts dc. The solenoid is designed to operate flags in indicators to MIL-1-22075 and for rotary motion military applications requiring low input and 35 deg total rotation.

No. 307 on Reader Service Card

CHECK VALVE—A new spring-loaded check valve for horizontal and vertical mounting insures full visibility with excellent corrosion resistance to most liquids. The stainless steel spring is completely sealed from liquids and gases by a Teflon enclosure, says **Chem Flow Corp., Dept. S/A, 161 Paterson Ave., Little Falls, N.J.** Model SL200 check valves are available in sizes 1, 1½, 2 and 3 in. and are adaptable to any pipe installation with 150 lb ASA companion flange. Max operating pressure is 50 psi. For higher pressure applications, other construction materials are available.

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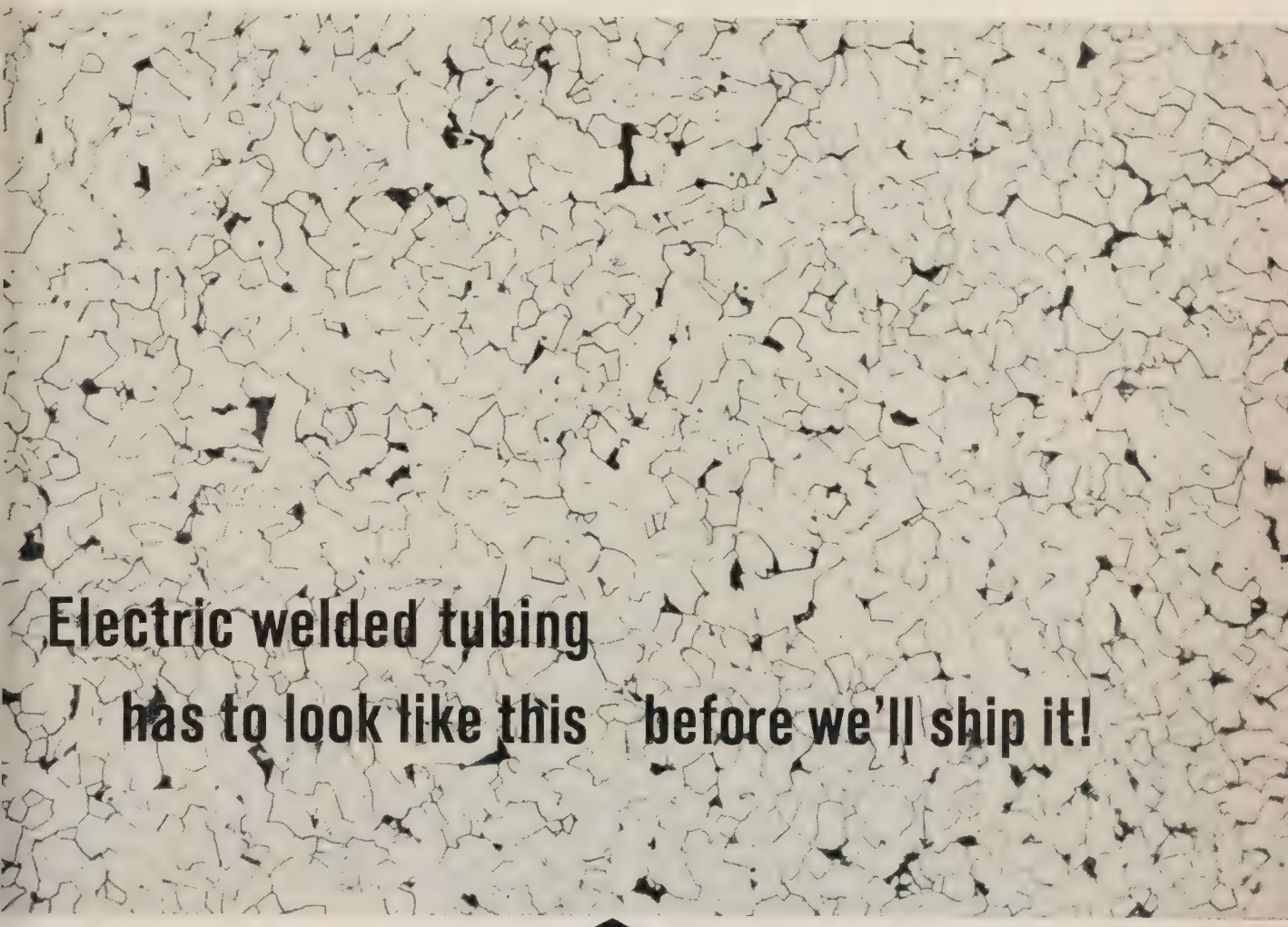

Electric welded tubing has to look like this before we'll ship it!

In this photomicrograph of a section of USS National Electric Resistance Welded Steel Mechanical Tubing the weld section runs right down through the center of the picture above the arrow. The consistency of structure between the weld area and the rest of the tube shows that USS National Welded Mechanical Tubing has an important attribute—dependability.

Mechanical tubing must be flawless. It's used in so many critical applications that demand utmost strength, excellent surface inside or outside and extreme dimensional accuracy. National Tube's production methods assure this high quality.

Important advantages of USS National Welded Mechanical Tubing are its ability to reduce machining operations to a minimum or eliminate them entirely. For a given weight, it withstands more load than any other section. It resists bending stresses equally in all directions. In torsion, it provides maximum material distribution.

USS National Welded Mechanical Tubing is available in cold-drawn or hot-rolled sizes ⅜″ thru 5½″ and in wall thickness .035″ to .250″. All sizes can be obtained from National Tube Distributors located throughout the country. They will gladly show how tubing can reduce your costs. *See your USS National Tube Distributor.* *USS and National are registered trademarks*

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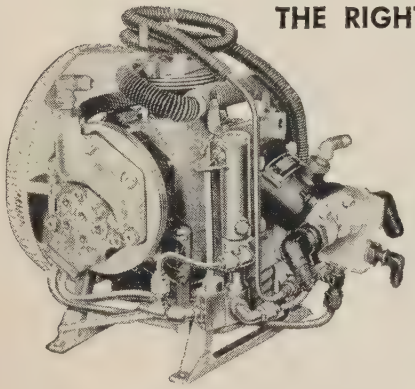

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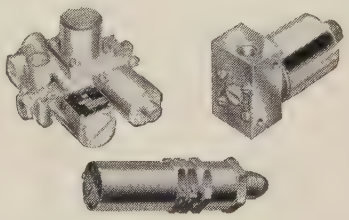

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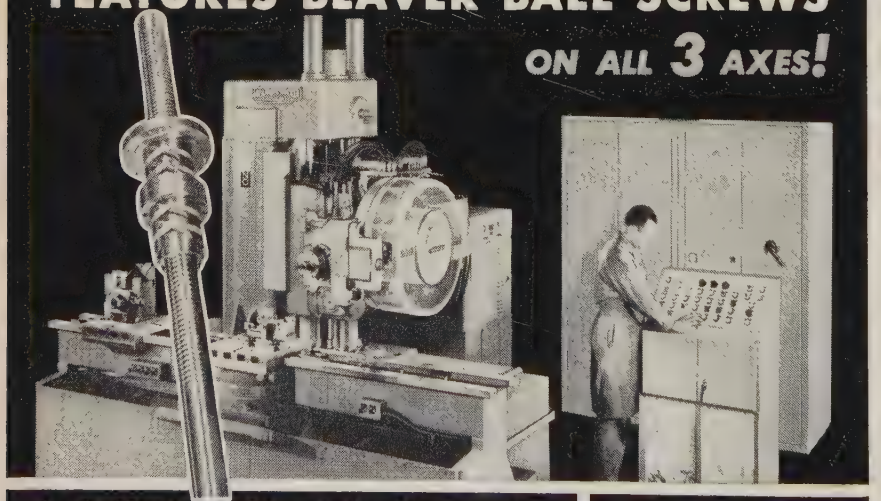

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Our engineers will be glad to work with you.

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No. 223 on Reader Service Card

THERMAL SWITCH — A thermal sensing device that withstands all the environmental conditions in aircraft applications has been developed by **Control Products, Inc., Dept. S/A, 280 Ridgedale Ave., Hanover, N.J.** The bimetal sensing device is hermetically sealed, highly sensitive and extremely accurate. It has a calibration range of −20 to +600 deg; repeatability is ±1 deg F. The switch measures ¼ x ¾ x 1 9/32 in. long, and weighs 0.9 oz.

No. 309 on Reader Service Card

FUEL PUMPS—A new series of pumps, specially designed for handling liquid monopropellants and fuels, has been designed by **Clevite Ordnance, Div. of Clevite Corp., Dept. S/A, 540 E. 105 St., Cleveland 8, Ohio.** The pumps provide volumetric efficiencies of better than 95 per cent over their operating range. They are suitable for service to 6000 rpm, and range from 6 to 7½ in. long and from 3½ to 5½ in. in diam. Weights range from 6 to 30 lb.

No. 310 on Reader Service Card

BLEED VALVE—A pneumatic bleed valve withstands pressures up to 14,000 psi and has an operating pressure of 6000 deg F. Designed by **Benbow Mfg. Corp., Dept. S/A, 11920 W. Jefferson Blvd., Culver City, Calif.,** it releases with 20 lb max of finger pressure at 6000 psi. The new design is said to be mechanically simplified to reduce cost and increase reliability.

No. 311 on Reader Service Card

FILTER ASSEMBLIES—A line of tee-type filter assemblies is now offered by **Aircraft Porous Media, Inc., Dept. S/A, 30 Sea Cliff Ave., Glen Cove, N. Y.** The units are available with options of built-in mounting pads, automatic shut-offs, magnetic filter elements, and differential pressure switches or indicators. Absolute removal rating is 15 to 230 microns, operating temperature is −65 to +1000 deg F.

No. 312 on Reader Service Card

MYLAR BELTS — Seamless Mylar belts precisely dimensioned to customer's specifications are available from **Kinelogic Corp., Dept. S/A, 1256 N. Fair Oaks, Pasadena, Calif.** Belts are made in lengths to 48 in., in widths to 1 in., and in thicknesses from 0.5 to 10 mils. Heat-treated for yield points to 18,000 psi, the belts are free of creep, set and stretch. With direct drives from shafts as small as 0.040 in., 10:1 ratio stages are easily realized.

No. 313 on Reader Service Card

CIRCUIT BREAKER —A new flight approved circuit breaker specifically designed to meet higher performance aircraft requirements is available from **Metals & Controls Inc., Div. of Texas Instruments Inc., Dept. S/A, 34 Forest St., Attleboro, Mass.** The "Klixon" 6752-12 breaker provides a rupture capacity of 6000 amp 120 volts ac or 30 volts dc. Ambient temperature compensation is from −65 to +250 deg F. Rated cycling life is 20,000 min. The unit measures 2⅛ by 1⅞ by ¾ in. and weighs 0.2 lb.

No. 314 on Reader Service Card

VALVE ACTUATOR —An electronic valve actuator developed for handling high pressure fluids in radioactive installations operates from standard 115 volt power. Developed by **Electro-Mech Corp., Dept. S/A, 500 Livingston St., Norwood, N.J.**, the actuator contains an electronic balancing relay assembly, which accepts any type of a-c or d-c control signal. The relay assembly produces an electrical corrective demand signal which controls the valve stem. Output torque is from 25 to 150 ft-lb., at speeds from ½ to 5 rpm.

No. 315 on Reader Service Card

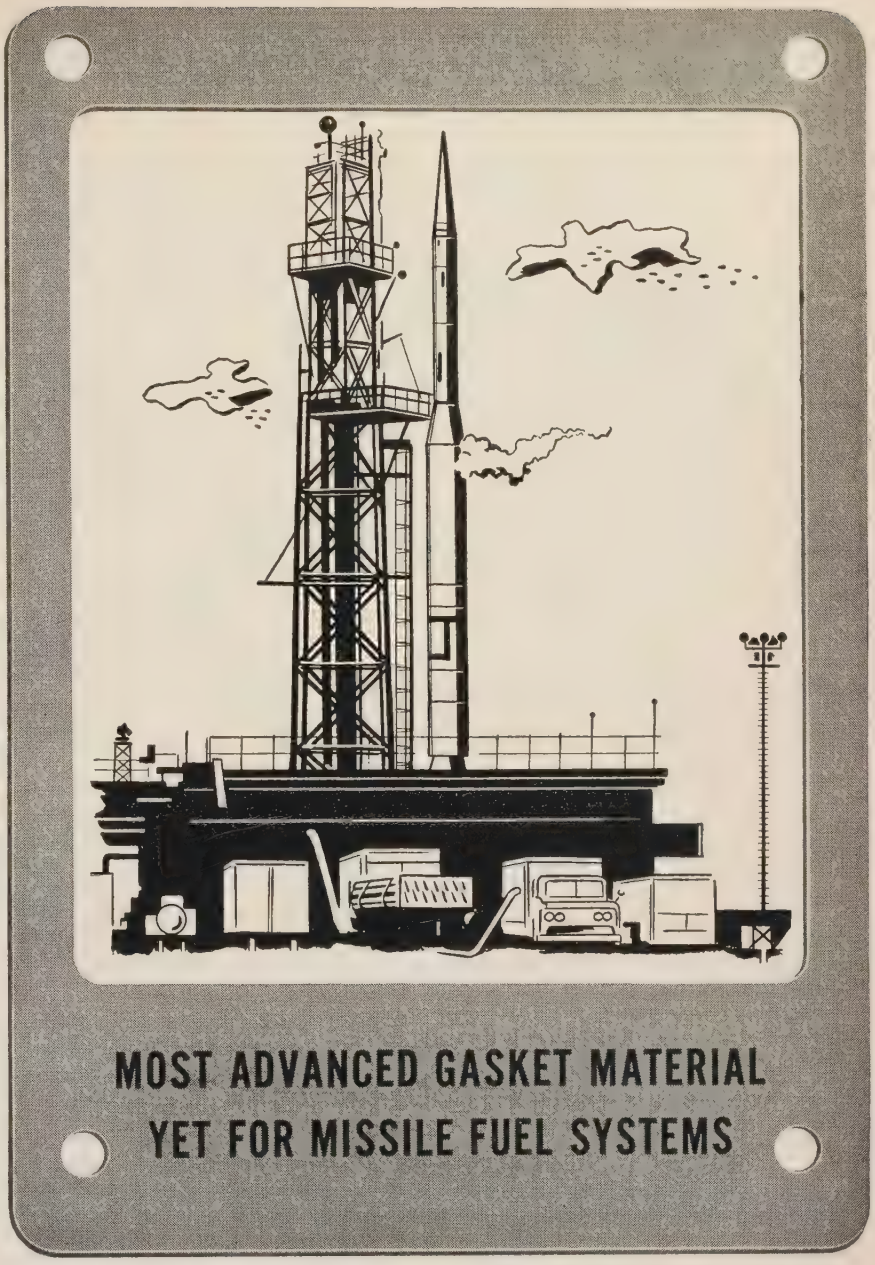
STATIC INVERTERS — Solid state static inverters providing single and three-phase outputs in a single compact module have been announced by **Pesco Products Div., Borg-Warner Corp., Dept. S/A, 24700 No. Miles Blvd., Bedford, Ohio.** Designed to meet requirements of MS-25096, Model R-143 uses silicon control rectifiers to provide positive reliability during simultaneous switching at high power levels. With an input of 25.0 to 30.0 volts dc, the three-phase output for the unit is 115 to 200 volts. The units measure 8 by 14 by 11 in. high and weigh 45 lb. Operating temperature range is −45 to +185 deg F.

No. 316 on Reader Service Card

DATA FILE

PHOTOVOLTAIC CELLS — Selenium photo-voltaic cells models 596, 857, 859, and 9971 are described in a 6-page product bulletin issued by **Weston Instruments Div., Daystrom, Inc., Dept. S/A, 614 Frelinghuysen Ave., Newark, N.J.** In addition to technical data information, it includes output versus illumination curves, dimension diagrams, and typical applications.

No. 317 on Reader Service Card



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Fluorobestos is available in standard sheets of 40 x 40 in., in thicknesses from .015 to .125 in. Write for complete information and test samples.

*Registered trademark for R/M reinforced asbestos Teflon sheet.
†Registered trademark for Du Pont fluorocarbon resins.

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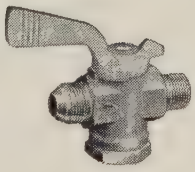
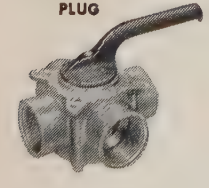


And special-purpose valves, too! There is one designed especially for drawing off accurate, minute samples for GAS CHROMATOGRAPHY analysis! Another, 3" and 4" SLURRY valves with rubber-covered rising plug for long service life! And a CYLINDRICAL plug type that features low pressure drop and easy turning.



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No. 103 on Reader Service Card

ACTUATOR—A 2-page bulletin describing an explosive-actuated, one-shot miniature piston actuator has been released by **Atlas Chemical Industries, Inc., Dept. S/A, Wilmington 99, Del.** It includes an exploded drawing, plus a dimensioned diagram. General characteristics such as firing energy, bridge and insulation resistance, and firing time are included. A broad range of applications is also given.

No. 395 on Reader Service Card

CONNECTORS—A six-page folder describing three separate lines of multiple connectors with specific data sheets for each of the lines, has been published by **AMP, Inc. Dept. S/A, Eisenhower Blvd. Harrisburg, Penna.** The data sheets give complete specifications on contact sizes, materials, wire crimp and insulation support, wire and insulation sizes, receptacles, and housings. Also described is their compression-crimp technique for attaching terminals.

No. 396 on Reader Service Card

LUBRICATION—The theory and use of solid lubricants is discussed in an 8-page brochure recently issued by **The Alpha-Molykote Corp., Dept. S/A, 65 Harvard Ave., Stamford, Conn.** It includes information on barriers to effective lubrication, properties of molybdenum disulfide as a dry-film lubricant, and actual descriptions of how solid lubricants have solved various problems. The brochure is illustrated with photos, graphs, line drawings, and charts.

No. 397 on Reader Service Card

BALL VALVES—Catalog 1200-A, published by **Hills-McCanna Co., Dept. S/A, Carpentersville, Ill.**, provides information on their line of manually operated and pneumatically operated ball valves. Valves described range from ¼ through 12 in. Pneumatic operators for automatic and remote on/off operation are described and illustrated. Five pages are devoted to suitability of standard body materials and various seat materials.

No. 398 on Reader Service Card

INSTRUMENTS—Electric quantity measurement instruments are the subject of bulletin GEA7688A, issued by **General Electric Co., Dept. S/A, Schenectady, N.Y.** The bulletin provides technical data on ac instruments such as ammeters, voltmeters; dc instruments such as ammeters and voltmeters; aircraft current transformers; and ground maintenance equipment such as an automatic-parallel systems tester and a phase sequence indicator.

No. 400 on Reader Service Card

FACILITIES—Engineering, testing, and production facilities available for the production of its line of gears and speed reducers are shown in a 4-page, full-color brochure, issued by **Ohio Gear Co., Dept. S/A, 1333 E. 179 St., Cleveland 10, Ohio.** Included in the brochure are their combination planetary and worm gear reducers for circuit breaker resetting, crank gears for a pump, special planetary gearing, power takeoffs and splined shafts for drive units, spur pinion shafts, and heavy duty hand operated reducers.

No. 401 on Reader Service Card

ACCELEROMETER—This 4-page booklet, entitled "Fairchild Sub-Miniature Linear Accelerometers", describes a line of accelerometers being manufactured by **Fairchild Controls Corp., Dept. S/A, 225 Park Ave., Hicksville, N.Y.** It contains performance data on two models, as well as a concise summary of basic accelerometer principles. Photographs, outline drawings, and cutaway views are also included.

No. 402 on Reader Service Card

SPRINGS—Comprehensive and detailed design data on Neg'ator constant force extension springs has been published by **Hunter Spring Co., Dept. S/A, Lansdale, Penna.**, in the form of a series of related data sheets. Included is a step-by-step procedure for designing these elastic members, along with 14 design tables. Other data are descriptions of load-deflection and size-load-life characteristics, mounting considerations, and applications.

No. 403 on Reader Service Card

TORQUE LIMITER—A pamphlet has been issued by **Saginaw Steering Gear Div., General Motors Corp., Dept. S/A, 3900 Holland Rd., Saginaw, Mich.,** describing their adjustable torque limiter. It lists 13 applications for these units. Also included is a brief description of how the limiter works.

No. 318 on Reader Service Card

SWITCHES—A 20-page catalog that lists and describes their full line of snap-action switches for electrical, electronic, and electromechanical applications is now available from **Cherry Electrical Products Corp., Dept. S/A, P.O. Box 66, Highland Park, Ill.** It includes illustrations, technical data, and ordering information.

No. 319 on Reader Service Card

SERVO-MOTOR—A compact servo-motor package featuring a highly integrated design is described in Bulletin A5261 available from **Vickers, Inc., Dept. S/A, P.O. Box 302, Detroit 32, Mich.** The 4-page bulletin includes complete details on design features and operating characteristics. Typical torque speed characteristics are shown in curve form, and a no-load static hysteresis loop is reproduced. Schematic and dimensioned drawings are included.

No. 320 on Reader Service Card

BRAZING ALLOYS—A brazing alloy chart, listing metal compositions, density, and melt and flow temperatures for Silvaloy silver brazing alloys and Engaloy precious metal brazing alloys, has been issued by **American Platinum and Silver Div., Englehard Industries, Inc., Dept. S/A, 113 Astor St., Newark, N.J.** It details 37 Silvaloy and 19 Engaloy compositions.

No. 321 on Reader Service Card

BEARINGS—"Bearing Parts and Nomenclature of Standard and Precision Bearings" is the title of a 24-page booklet which has been issued by **SKF Industries, Inc., Dept. S/A, Front St. & Erie Ave., Philadelphia 32, Penna.** It includes ball installation, dimensions, loads, alignment, types, and functions. Accessories such as shields, seal, rings, seats and housing are also decribed.

No. 322 on Reader Service Card

CLUTCHES & BRAKES—Catalog 963 has been prepared by **Dial Products Co., Dept. S/A, 19 Cottage St., Bayonne, N.J.,** showing many possible Dial clutch and brake combinations. Those covered are coupled by means of a double version pole-shoe assembly. Also included are definitions of components and general data on combinations. The catalog also covers tension controls and miniature flexible couplings.

No. 323 on Reader Service Card

BATTERY—A technical data sheet describing its new seawater battery has been issued by **Yardney Electric Corp., Dept. S/A, 40-50 Leonard St., New York 13, N.Y.** As described in the literature, the battery is a one-shot unit consisting of silver-chloride and magnesium duplex electrodes, and is activated by the flow of seawater through it. It can be stored indefinitely, says the company.

No. 324 on Reader Service Card

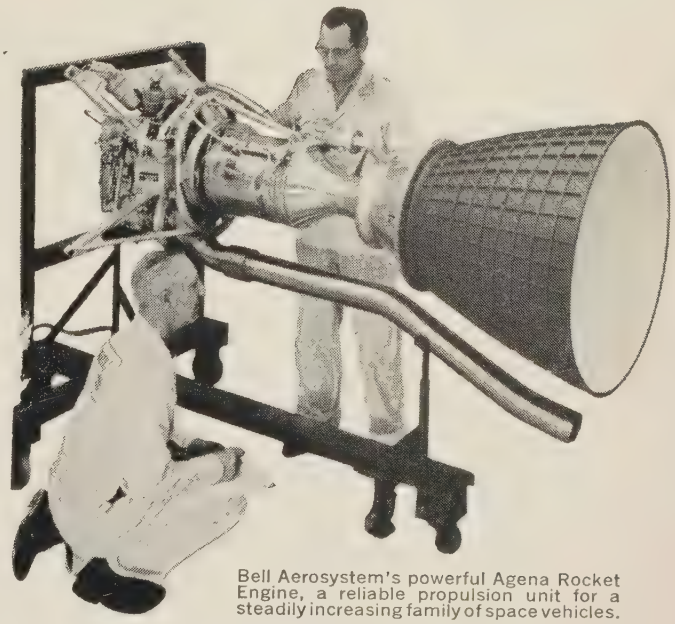
BALL BEARING SCREWS—In an illustrated publication called "The Actuator," **Saginaw Steering Gear Div., General Motors Corp., Dept. S/A, Saginaw, Mich.,** covers several applications of their ball bearing screws. One such description covers use of a 33-foot screw on a rifle broaching machine. Another describes the use of a Saginaw ball bearing screw in the valve actuating mechanism of a reducing valve.

No. 325 on Reader Service Card

CABLE—A new design in their line of Spectra-Flex extensible cable is described in a bulletin issued by **Spectra-Strip Wire & Cable Corp., Dept. S/A, P.O. Box 415, Garden Grove, Calif.** In addition to describing this new conical helix cable, it also gives information on their composite and coil type extensible cables.

No. 326 on Reader Service Card

Scheduled for the Moon ...and Beyond



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No. 104 on Reader Service Card

BATTERY—Remotes or manual activated silver-zinc batteries are discussed in a technical bulletin prepared by **Electro Energy, Inc., Dept. S/A, 7613 Alondra, Paramount, Calif.** The literature details specifications, new features, and applications. The latter include missile power, air drone power, telemetry power, and space vehicles.

No. 327 on Reader Service Card

COUPLINGS—Engineering data is now available from **Sterling Precision Corp., Dept. S/A, 17 Matinecock Ave., Port Washington, N.Y.**, on their subminiature to medium size hi-flex couplings. These sizes are reported applicable where backlash and cyclic angular variations between two shafts cannot be tolerated.

No. 328 on Reader Service Card

SEALS—An illustrated folder entitled "How O-Rings Seal" has been issued by **Seals, Inc., Dept. S/A, 393 Central Ave., East Orange, N.J.** It shows the O-ring with no fluid pressure applied and with fluid pressure applied, describing how the seal reacts to pressure. Also, an explanation is given for the O-shape of the seal. A sample O-ring is included in the folder.

No. 329 on Reader Service Card

BEARINGS — Self-aligning bearings and rod end bearings are covered in catalog 551, issued by **Southwest Products Co., Dept. S/A, 1705 S. Mountain Ave., Monrovia, Calif.** It gives instructions for specifying particular types of bearings, eg., lubrication grooves, solid lubricant, etc. Specifications are given for different series of baerings in tabular form. Outline drawings are also included.

No. 330 on Reader Service Card

SWITCHES & THERMOSTATS—Forty-two representative Klixon precision switch packages and thermostat packages are shown in each of two revised technical bulletins, published by **Metals & Controls, Inc., Dept. S/A, 34 Forest St., Attleboro, Mass.** Included in these bulletins are photos and dimensional drawings of representative packages.

No. 331 on Reader Service Card

SOLAR POWER—Solar dynamic space power is the subject of a pamphlet issued by **Sundstrand Aviation, Dept. S/A, 2480 W. 70 Ave., Denver 21, Colo.** It shows an artist's conception of a solar dynamic power system, giving descriptions of the major system components. Component weights and dimensions are given in tabular form.

No. 332 on Reader Service Card

RPI space age support provider

NEW
UNIVERSAL
EJECTOR
RACK

. . . handles any
SUSPENDABLE
STORE

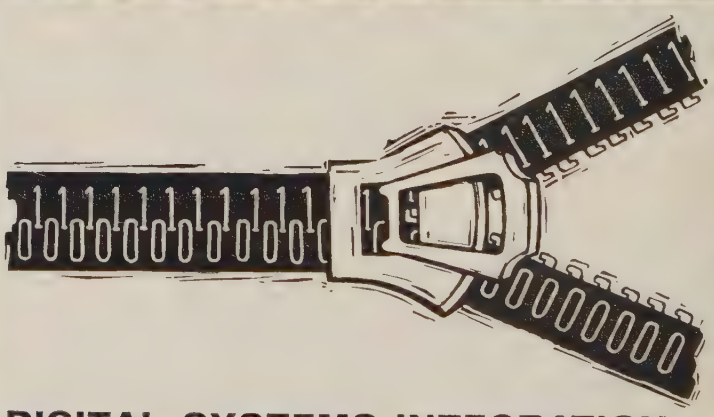
Cut costs and installation problems with this unique Rocket Power "all purpose" rack, the MAU12/A, first to handle so wide a variety of stores—special weapons, missiles, conventional bombs, camera pods, and auxiliary tanks.

Developed for the U. S. Air Force Special Weapons Center for use on several Fighter-bombers, Bombers and V/STOL aircraft, this RPI rack features *adjustable* ejection force and all required safety devices. It is easily attached to the aircraft and provides both 14" and 30" hook spacing.

FOR TECHNICAL DATA on the RPI Universal Ejector Rack write for Bulletin #1500.

ROCKET POWER INC.
FALCON FIELD/MESA, ARIZONA
OFFICES: Pasadena/Dayton/Washington, D.C.

No. 105 on Reader Service Card



DIGITAL SYSTEMS INTEGRATION

Can you integrate the developmental sub-systems of a digital tactical data system into a smoothly functioning prototype system? Can you do this with a view towards testing, evaluating, modifying, and enhancing the system and without losing sight of interaction, trade-off, reliability, and logic efficiency? If affirmative, write to Mr. S. L. Hirsch.

An Equal Opportunity Employer

LITTON SYSTEMS, INC. Data Systems Division
Canoga Park, California

Check Inquiry Form on Page 131

Check Inquiry Form on Page 131

f you are a hardware-oriented engineer who enjoys the shirt-sleeved tmosphere of field assignments, General Dynamics | Astronautics as a number of important assignments in the activation of Atlas CBM bases throughout the United States. The basic task is roviding a wide range of technical assistance to the Air Force in ringing bases to operational capability.

ase Activation Engineers function at the systems level in the instal- tion, checkout, and acceptance of ground support and missile- orne equipment. Specific requirements and locations of work are etailed on the back of this page.

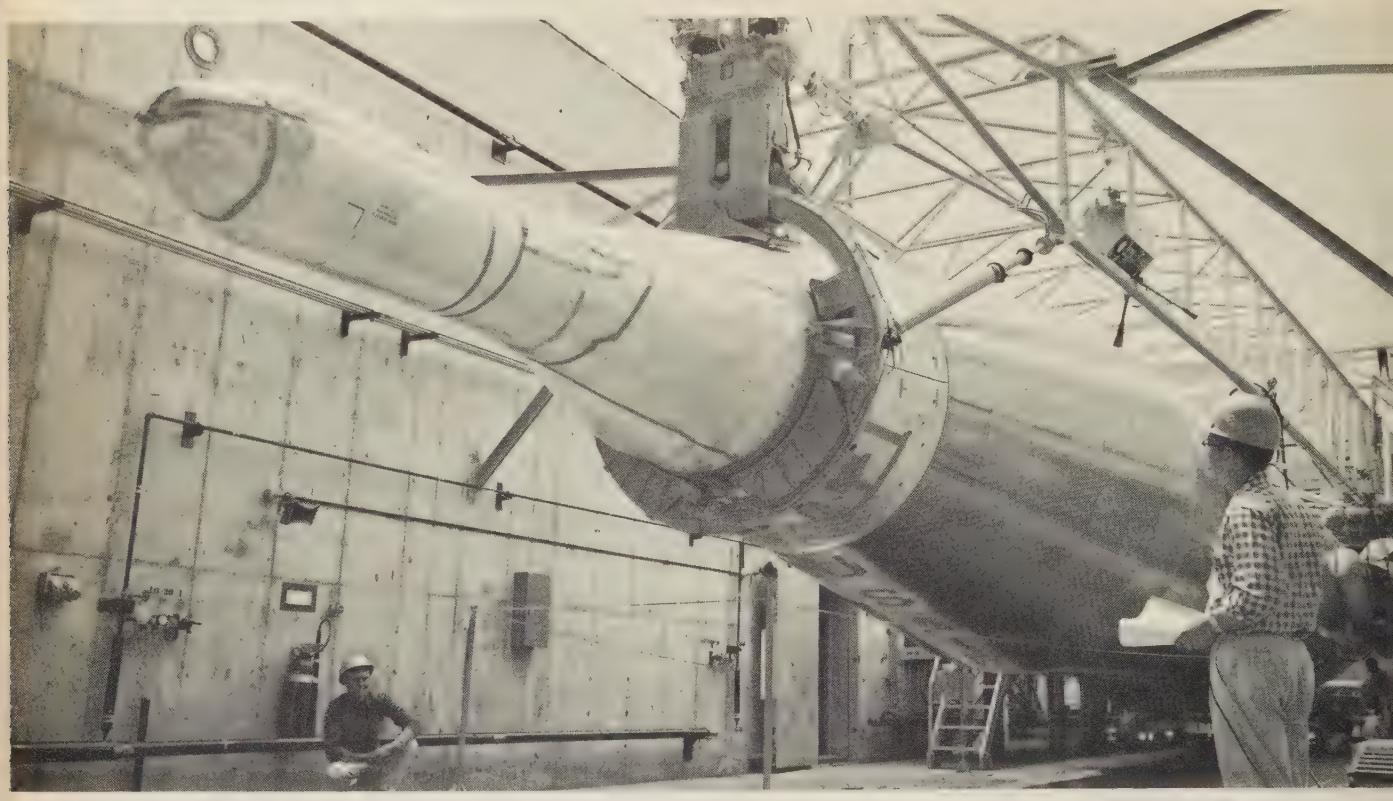
hese positions provide stability, growth opportunity, and the tisfaction of working on a program which is not only technically dvanced, but of vital significance to the security of the free world.

For a prompt, confidential reply, use the attached Professional Placement Inquiry card or write to Mr. R. M. Smith, Industrial Relations Administrator-Engineering, Department 130-90, General Dynamics | Astronautics 5708 Kearny Villa Road, San Diego 12, California. Candidates who live in the New York area may find it more convenient to contact Mr. T. Cozine or Mr. E. Hart, General Dynamics | Astronautics, 1 Rockefeller Plaza, New York, telephone, CIrcle 5-5034.

GENERAL DYNAMICS ASTRONAUTICS

FORMERLY CONVAIR / ASTRONAUTICS

ENGINEERS FOR BASE ACTIVATIO



ATLAS MISSILE shown in horizontal launcher at operational base. Current assignments for base activation engineers are a Oklahoma; Abilene, Texas; Roswell, New Mexico; Plattsburgh, New York.

DESIGN/LIAISON ENGINEERS

Tasks involve liaison and design support work in connection with launch control equipment, propulsion systems, automatic programming and missile checkout equipment. A degree in mechanical or electrical engineering and systems experience desired.

ENGINEERING WRITERS

To prepare maintenance, operation, and inspection manuals, and engineering proposals. At least two years of college engineering and 1 to 3 years of experience in this field desired.

FIELD SERVICE ENGINEERS

Assignments are for specialists capable of represen the company to the Air Force in technical aspect the Atlas ICBM. An engineering degree and field exp ence desired.

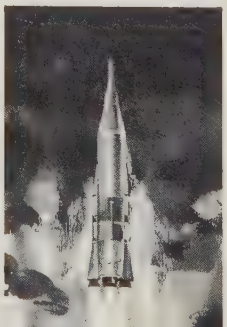
ELECTRICAL/ELECTRONIC ENGINEERS

Graduate engineers with field experience in lau controls, logic control systems, automatic chec equipment, guidance and flight control, facility elect power, electronic systems, R.F. systems, telemete landlines, or autopilots.

For a prompt reply and a personal interview in your area, complete and mail the attached Professional Placement Inquiry today. If it has been removed, write to Mr. R. M. Smith, Industrial Relations Administrator-Engineering, General Dynamics|Astronautics, Dept. 130-90, 5708 Kearny Villa Road, San Diego 12, California. (If you live in the New York area, please contact Mr. T. Cozine or Mr. E. Hart, 1 Rockefeller Plaza, CIrcle 5-5034.)

LIBERAL ALLOWANCES ARE PROVIDED
MEN ASSIGNED TO FIELD OPERATIONS

AN EQUAL OPPORTUNITY EMPLOYER.



GENERAL DYNAMICS ASTRONAUTICS

FORMERLY CONVAIR / ASTRONAUTICS

CRYOGENIC VALVE—Technical data on a cryogenic valve featuring high flow capacity are given in a data sheet issued by **Valcor Engineering Corp., Dept. S/A, 365 Carnegie Ave., Kenilworth, N.J.**, on their series V-41600 valves. In addition to specifications, the data sheet gives a wiring diagram, dimensions, and a cutaway view of this floating-seal valve.

No. 261 on Reader Service Card

FUEL PUMP — Fixed displacement, vane-type fuel pumps are described in a 6-page bulletin just released by **Vickers, Inc., Dept. S/A, P.O. Box 302, Detroit 32, Mich.** This bulletin A-5242A includes photographs showing various pump configurations, typical fuel pump performance curves, schematic diagrams, and a sketch showing principles of vane design. Specs for various pump models are given in tabular form.

No. 262 on Reader Service Card

HYDRAULIC MOTOR — Variable displacement hydraulic motors featuring high efficiency and control accuracy are the subject of Bulletin A-5238, issued by **Vickers, Inc., Dept. S/A, P.O. Box 302, Detroit 32, Mich.** Principles of operation and performance data are included. A typical oscillograph shows the response to step load changes. Specs and outline drawings are given for typical generator drive units. Data are presented on horsepower versus unit size for preliminary design purposes.

No. 263 on Reader Service Card

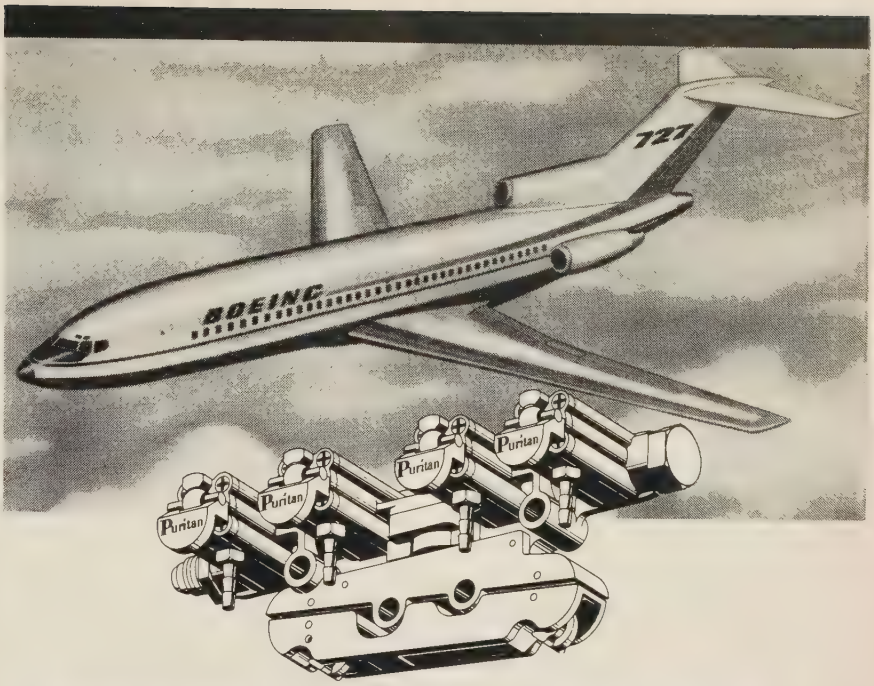
SERVO INDICATOR—Technical data, block diagrams, and dimension drawings are all included in a product specification sheet issued by **Consolidated Airborne Systems, Inc., Dept. S/A, 900 Third Ave., New Hyde Park, N.Y.**, on their servo-indicator airborne instrumentation for temperature control and measurement. It also includes a family tree showing how the design features of this instrumentation are applicable to other measure ments and control devices.

No. 264 on Reader Service Card

DIFFERENTIALS — Mechanical differentials are covered in brochure 8101, published by **Dynamic Gear Co., Inc., Dept. S/A, 175 Dixon Ave., Amityville, N.Y.** Contents of the brochure include general differential information, such as backlash, torque, etc., a series of engineering drawings on stock and pre-engineered differentials, and a test report on their D-156 differential. The latter includes a mathematical analysis and various performance curves.

No. 265 on Reader Service Card

Check Inquiry Form on Page 131



PURITAN RIDES the BOEING 727

. . . FOR GREATER PASSENGER SAFETY. Puritan's automatic valve assembly for passenger outlet stations has been specified for the oxygen breathing systems in the Boeing 727. It is a compact, integrated unit with all the valves and the latch combined, and enables passengers to be supplied with emergency oxygen if needed.

Your inquiry on any problem concerning high altitude breathing systems and equipment would be welcome.

Puritan's automatic valve assembly is mounted in the Passenger Service unit above the passengers, and in the lavatories.

AEROSPACE DIVISION
Puritan EQUIPMENT, INC.
1703 McGee Street • Kansas City 8, Mo.
A subsidiary of PURITAN COMPRESSED GAS CORPORATION

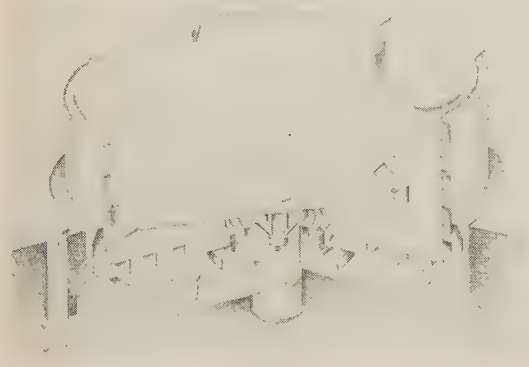
BREATHING LIFE INTO AIR AND SPACE TRAVEL

No. 106 on Reader Service Card

DESIGN DEVELOPMENTS

For more details on the equipment, processes, and facilities described in this section,

APOLLO CENTRIFUGE TO DEVELOP 50,000 g-lb

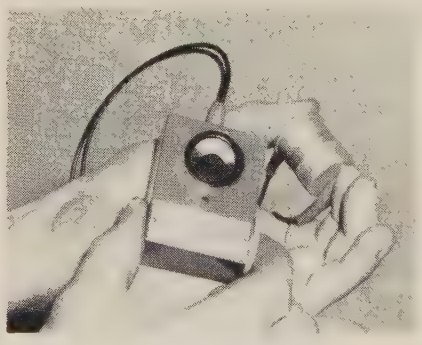


To test components for the Apollo program, a requirement of 50,000 g-lb has been set by NASA's Langley Research Center, for a centrifuge to be built by Trio-Tech Co., 3410 Cohasset St., Burbank, Calif. Specimens weighing 50 lb will be rotated to acceleration forces of 100 g a unit with an off-set rotating arm that will swing in a 41-ft diameter arc.

With the centrifuge arm enclosed in a 50-ft vacuum chamber, it will be possible to run these tests at simulated altitudes of up to 200,000 feet. Seals between power head and rotor hub will provide an atmosphere of 200 microns Hg absolute. Added sealing will prevent leakage when the chamber is evacuated down to 10^{-4} mm Hg, or about 350,000 feet altitude.

The system will be powered by three electric motors furnishing a total of 500 hp and connected directly to five hydraulic pumps driving three hydraulic motors. Provisions will be made for supplying either electrical or hydraulic power to the unit under test.

Tester for Highly Explosive Connections



An extremely low-powered meter designed to test across the most sensitive explosive connections —e.g., the mechanism that triggers giant rocket motors on the launching pad—without risk of an inadvertent misfire, has been developed at Johns Hopkins University's Applied Physics Laboratory, 8621 Georgia Ave., Silver Spring, Md. Measuring resistances on the order of 0.1-10,000 ohms, the meter can be used for last-minute checks on continuity and reliability of these hazardous circuits.

An extremely low current is generated by a self-contained light shining on a silicon photo-cell. The light-generated power from this cell is connected to the meter test leads. This makes it possible to check out the most sensitive bridgewire explosive charges—the current is so minute that it would not ignite a sensitive charge even if it were amplified 300 times.

The meter is one of the instruments developed by APL as part of a submarine testing program for the Polaris missile system. In the Polaris' electric system sensitive and minute but critical electric connections can become contaminated during the long periods over which the equipment must stand by ready for launching.

In fact, most failures of electrically actuated explosive components can be directly traced to basic power sources that did not provide the required power because of faulty connections or the deterioration of explosive ignition elements with the passage of time.

All-Glass Shock Tube for Better Photo-Recording

This low-cost, all-glass shock tube generating shock waves of 280,000 mph is being used to study problems of spacecraft re-entry at Mach 400, reports Lockheed Missile & Space Co., Sunnyvale, Calif. Its all-glass construction is ideal for direct observation and photographic recording of shock phenomena. Using time exposures, researchers are able to photograph an entire event in the tube—a considerable advance over the limitations of the single window in the traditional metal tube. Lockheed expects to use the tube for detailed analyses of thermal radiation effects.

Ordinarily, the six-inch-ID, 10-ft-long tube is operated at an initial pressure of 10 microns. The shock wave is driven by electromagnetic forces generated by the discharge of a capacitor storage bank that can store 60,000 J. When the wave moves through the gas in the tube (air or nitrogen), it heats the gas to temperatures on the order of 100,000 deg K.

Testing and Support

write in item numbers on Reader Service Card

Spotting Trace Quantities of Propellant Vapors

A portable electronic unit has been developed to detect trace quantities of toxic rocket propellant in the atmosphere. It has sensitivities of one part in four million for hydrazine and UDMH vapor and of one part in one million for nitrogen tetroxide, says American Systems, Inc., 1625 E. 126 St., Hawthorne, Calif. The complete unit weighs 16 lb.

Powered by a rechargeable wet battery, the detector puts out an electric signal proportional to the concentrated vapors. These signals can be fed to alarm or purging systems. The unit may also be set up with recording and control equipment for unattended service at remote storage sites. **61**

Shaker and Test Chamber in One Unit

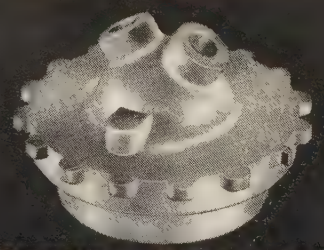
A "two-in-one" electrodynamic shake and environmental tester has been introduced by Ling-Temco Electronics, Inc., 1515 S. Manchester, Anaheim, Calif. The basic shaker, which has a 5000-lb force rating, has a maximum load limit of 450 lb for 10-g-vector and 200 lb for 20-g vector tests. The frequency range is 5-3000 cps; maximum acceleration is 100 g.

The hermetically sealed Model 300 shaker "piggy-back" environmental test chamber has a temperature range of —100 to 350 deg F. Humidity and altitude are said to be unlimited. A novel closed-loop cooling system is used for the field and armature structures, according to the manufacturer. **62**

VALVE — A newly patented device for use in hydraulic, fuel, or pneumatic systems automatically stops flow to gage at excess pressure. Available in stainless steel or aluminum from **Fisher Control, Inc., Dept. S/A, 1754 Twenty-second St., Santa Monica, Calif.**, the units are fully adjustable from 50 to 5000 psi. These valves are machined from ⅞ hex stock and are 2 in. long, including ½-14 NPT (male) connections at each end.

No. 255 on Reader Service Card

STRONG-TOUGH ...To Withstand Extreme Stress And High Temperature



Casting Engineers Investment Casting For Rocket Igniters

■ This large, high-strength structural steel casting, produced for Thiokol Chemical Corp., Redstone Division, is an adapter for igniters used in solid propellant rocket motors.

The component exceeded rigid specifications—**no defects were permitted** and proved 100% reliable under the extreme pressures and temperatures that were encountered in flight.

The remarkable MONOCAST ceramic shell technique, exclusive with Casting Engineers, reduces or eliminates machining and secondary operations, minimizes rejects, and provides new design freedom for complex configuration. MONOCAST units are precision, high-density castings produced with repetitive precision in volume quantities. Casting Engineers has the ability and facilities to provide you with precision investment castings to meet the toughest requirements of space vehicles or down-to-earth industrial applications.

Whether your application requires the new MONOCAST ceramic shell technique for relatively large parts, or our high-volume MINICAST process for small components, Casting Engineers guarantees maximum production efficiency at lowest cost.

SPECIFICATIONS

Material	4340 high-strength structural steel
Minimum Requirements:	
Yield Strength	160-180,000 psi
Elongation	7%
Typical Results:	
Tensile Strength	195,000 psi
Yield Strength	180,000 psi
Elongation	9-10%
Overall Diameter	5½"
Weight	4½ lbs.
Inspection	100% X-Ray, Class 1A, no defects allowed

Free brochure tells how to cut costs by specifying investment castings. Write for your copy now.

Casting Engineers

Plants in Chicago and New York City

Address Inquiries to:

2329 N. Bosworth Ave. • Chicago 14, Ill.

MINICAST BUckingham 1-5940 MONOCAST

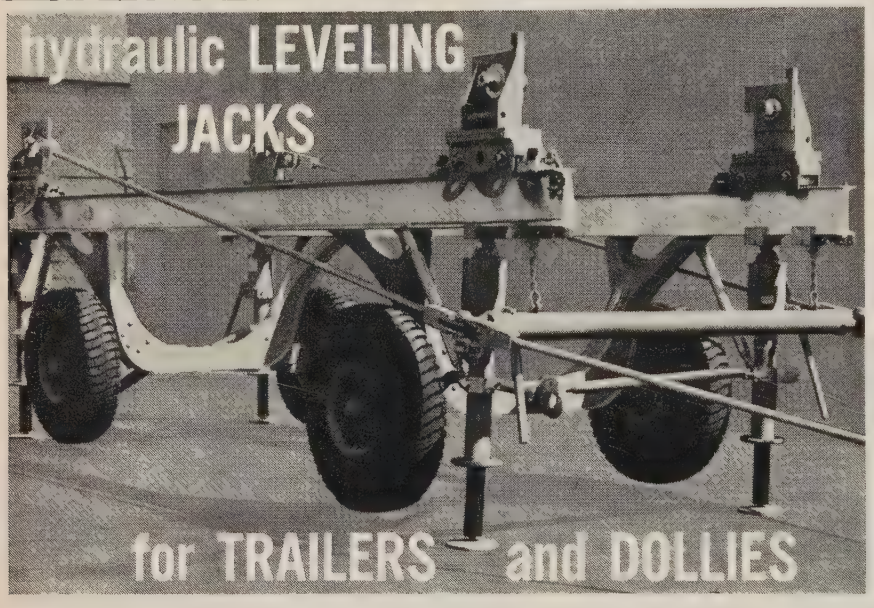
No. 107 on Reader Service Card

BLOWER—A vaneaxial blower, operating on 115 volts ac or dc and delivering 68 cfm of air at 1.5 in. of static pressure, is now available from **Globe Industries, Inc., Dept. S/A, 1784 Stanley Ave., Dayton 4, Ohio.** Designed primarily for use in ground support equipment, the unit weighs only 1 lb, and measures 3¼ in. long by 3 in. diameter. An integral propeller shroud and motor housing is precision cast, and is designed to meet pertinent MIL specs.

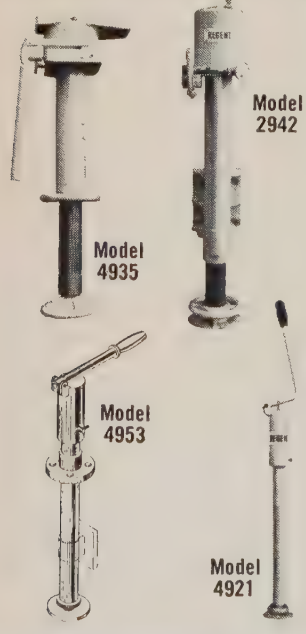
No. 256 on Reader Service Card

COMPONENT TESTERS—A series of test machines designed to check out hydraulic components is now available from **Greer Hydraulics, Inc., Dept. S/A, 5930 W. Jefferson Blvd., Los Angeles 16, Calif.** The line comprises 10 basic models, available in 5 console sizes. Machines are rated for 5000 psi maximum, 3000 psi normal pressure, with flows of 5 to 60 gpm, static test circuits to 25,000 psi, and horsepower ratings from 10 to 100. All controls and ports are arranged for easy operational use. Gages and other instrumentation are equipped for contamination-free calibration, without removal. Gages are 6 in. dials and guaranteed to 1 percent accuracy. Flow meters are guaranteed to 2 percent. All operating valves are cartridge units which can be serviced from outside the machine.

No. 257 on Reader Service Card



Quick-acting . . . Self-retracting



Fast acting (six-times faster!), Regent hydraulic leveling jacks are easy to use . . . dependable even under most difficult operating conditions. Whether used at forward-field or fixed-base, Regents are sure-footed, virtually effortless. Step, and the ram descends silently and quickly – locking the footpad to the ground. Just a few quick movements of the hand-pump handle, and the trailer lifts off the ground, locks in place. Then – just flick the valve and the ram retracts to lower the trailer to the ground, then automatically continues on to fully-closed position. Compact Regents are available in standard units from 2 to 50 tons capacity. Or we can engineer to your special requirements.

Hydraulic leveling jacks for aircraft and missile transport trailers and missile launchers.

MODEL NO.	4953	4935	2935R	2942	4973
Vertical Capacity (tons)	2	5	5	5	3
Min. Closed Height (in.)	23½	22	26	32	22¾
Hydraulic Lift (in.)	10	10	10	15	14¾
Working Pressure (psi)	4650	1670	2020	1670	1000
Net Weight (lbs.)	15	48	63	72	–

REGENT

REGENT JACK MANUFACTURING CO., INC.
11905 Regentview Avenue
Downey, California • SPruce 3-0103

TEMPERATURE DETECTOR—This resistance temperature detector with resistance wires interwoven with fiberglass threads provides a rugged, accurate, inexpensive sensing element, according to **Control Indicating Corp. Dept. S/A, Bradley Field, Windsor Locks, Conn.** These units are available in a variety of widths, from ½ to 3 in. Because of its physical construction, total length is never a limiting factor, says the company. Special detectors can be provided to fit irregularly shaped surfaces. Platinum or nickel wire are used, making the detectors suitable for use to 1000 deg. F.

No. 258 on Reader Service Card

PRESSURE TRANSDUCERS — A series of pressure transducers, designed to provide measurements with ambient temperatures up to 1000 deg F and to have high resistance to nuclear radiation is being marketed by **Consolidated Controls Corp., Dept. S/A, Bethel, Conn.** These units provide nominal full scale output of 200 mv with an accuracy of 2½ per cent, over a temperature range from –65 to 1000 deg F. Accuracy is reported ½ per cent at room temperature. The all solid-state circuit consists of an ac regulator and demodulator, and contains an oscillator power supply. Resonant frequency varies from 200 to 2000 cps. Input power is 110 volts ac at 60 or 400 cps and 28 volts dc.

No. 259 on Reader Service Card

TACHOMETER GENERATORS – The development of a line of tachometer generators for application with precision rate table drivers has been announced by **Inland Motor Corp. of Virginia, Dept. S/A, Northampton, Mass.** This type T10.0 unit has a sensitivity of 48 volts/rad/sec, linear over a speed range from 0.1 earth rate (1.5 sec of arc/sec) to 20 rpm, with a maximum instantaneous error of 0.25 percent of actual value. The output of the tach generator portion of the unit is compared to a reference dc voltage. The difference is amplified, stability compensated, and fed to a torque motor. Thus, the reference voltage, read to 0.1 percent accuracy, provides instantaneous rate information with a maximum possible error of 0.35 percent.

No. 260 on Reader Service Card

No. 108 on Reader Service Card

No. 165 on Reader Service Card

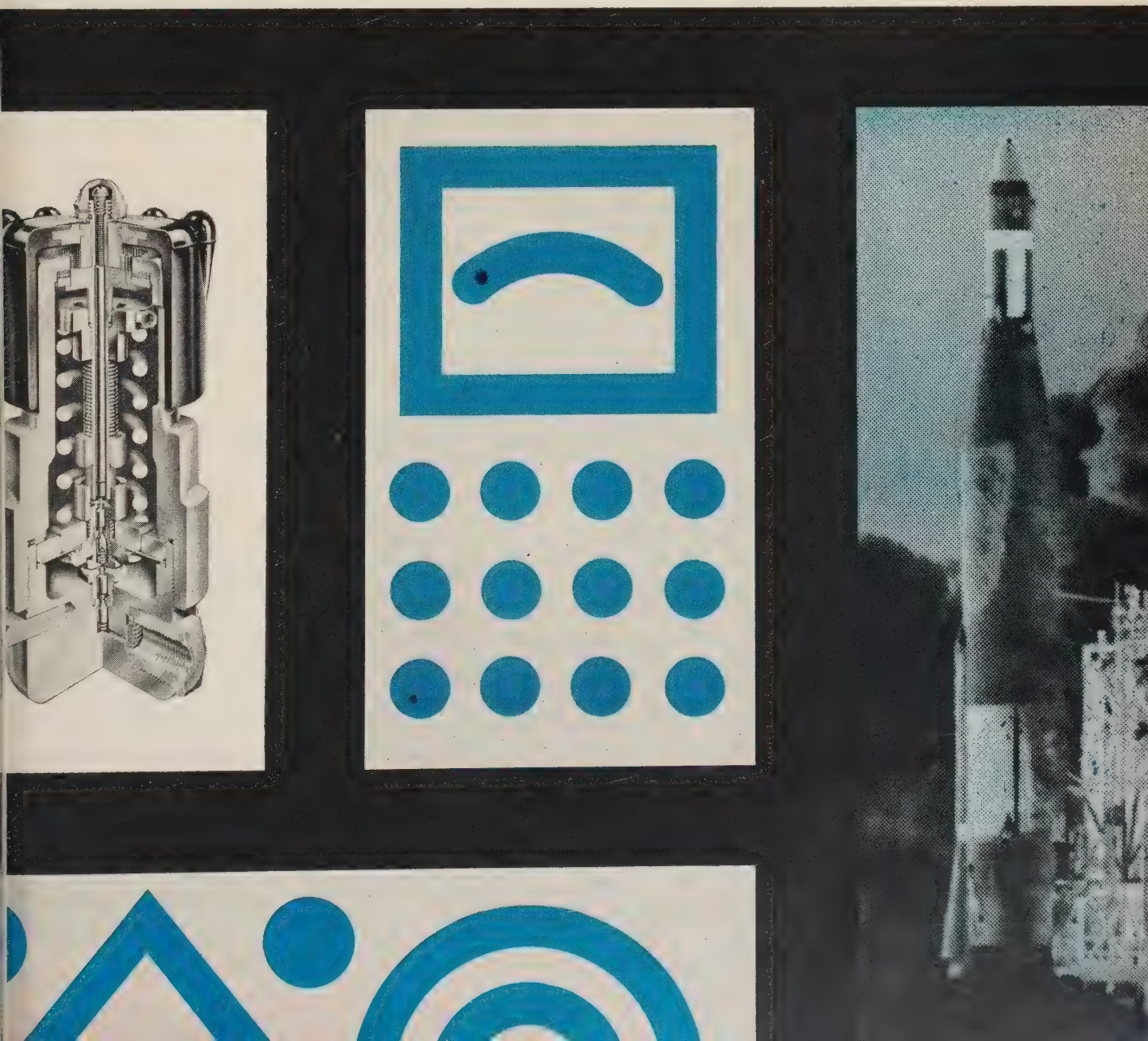
GROVE FIRST!

NSTRUMENT ACCURACY IN A PRESSURE REGULATOR

rove Low Flow Rate, High Pressure Reducing and Relieving Regulators. Even at very high differential and rying inlet pressures, Extreme Accuracy is possible because of the very large diaphragm-to-valve orifice ratios Grove model 15 "loaders." Smooth Control when changing setting, without overshoot or undershoot, is achieved super-sensitive handwheel adjustment. The simplicity and quality designed into Grove hand loaders gives nger Service Life with minimum maintenance. Although designed primarily for panel mounting in test facilities, e Reliability, accuracy and light weight of Grove loaders qualifies them for service in airborne vehicles. Offered th motor actuators for remote operation. Wide range of models to serve from 0 psi to 6000 psi. Send for echnical Presentation 125-C, Rev. 1. *Another Way Grove Sets Regulator Standards for Others to Follow*

GROVE REGULATORS **GROVE VALVE AND REGULATOR COMPANY**

ubsidiary of Walworth • 6529 Hollis Street, Oakland 8, California



Now NO-BLADE Stripping makes wire damage impossible!

New IDEAL

THERMO-STRIP

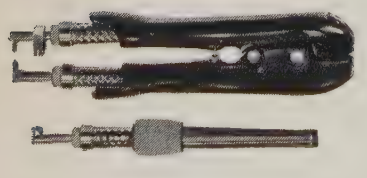
FOR PLASTIC INSULATION

- For use where absolutely no wire damage is permissible
- Can operate continuously—no warm-up delay
- Infinitely variable heat control—prolongs element life—reduces fumes

Especially designed to meet zero-defect requirements in assembly of missiles components, aircraft, computers and other precision electronic systems and instruments, the new Ideal Thermo-Strip Hot Wire Stripper completely eliminates the possibility of nicks, breaking or disturbing of strands in even the finest wires. *Not* just a converted soldering iron, it is all new, light-weight, easy-to-use, and safely removes all types of thermo-plastic insulation, including Teflon.

COMPLETE . . . READY TO USE . . .

Includes 50-watt transformer and tool of your choice. (Shown with Pincer mounted for high-speed production stripping.)



PINCER
Just grip wire, twist, and pull off insulation slug with heating elements.

SINGLE LOOP
For "probing" into miniature or crowded assemblies. Just put wire end in V-notch of electrode.

Sold Through America's Leading Distributors
IN CANADA: IRVING SMITH, Ltd., Montreal

Elements may be formed for any wire size or particular service.

ARRANGE A TRIAL! MAIL TODAY

IDEAL INDUSTRIES, Inc.
1435-L Park Avenue, Sycamore, Illinois

☐ Have your representative arrange a trial for me. ☐ Send data only now.

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Company_____

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City_____ Zone_____ State_____

No. 109 on Reader Service Card

ENVIRONMENT TEST CHAMBER—A temperature-humidity test chamber that has no mechanical refrigeration system, either for low temperature or dehumidity conditions, has been developed by **Associated Testing Laboratories, Inc., Dept. S/A, Wayne, N.J.** This model ELHH-4-LC unit has internal working dimensions of 18 cu in., and uses liquid CO_2 refrigeration to achieve temperatures as low as —100 deg F and to control humidity in the 20 to 95 percent RH range. High temperature range is to 350 deg F. A two-pen recorder is included as standard equipment with the chamber.

No. 333 on Reader Service Card

PULSE CALIBRATOR—This portable pressure pulse calibrator permits calibration of complete dynamic pressure recording systems, says **Atlantic Research Corp., Dept. S/A, Alexandria, Va.** It provides 3 ms rise time from atmospheric to pressures up to 1000 psi. The calibrating pressure is indicated on a gage supplied with the unit. Pressure on the transducer is vented by releasing a poppet valve. Scales on the gage are available from 0-5 to 0-1000 psig. Accuracy and linearity are reported better than 0.1 percent.

No. 334 on Reader Service Card

CAMERA SYSTEM—An ultra high speed Kerr cell camera system, suitable for hypervelocity particle ballistic range, has been announced by **Electro-Optical Instruments, Inc., Dept. S/A, 3612 E. Foothill Blvd., Pasadena, Calif.** When used to instrument a multiple observation range individual shutter modules can function as far as 60 feet from the control center. For single observations, the camera can be used as high speed framing cameras which rates to 10^8 frames per second. Exposure times of 20 nsec are guaranteed —and exposure times of 10 nsec have been achieved.

No. 344 on Reader Service Card

MULTITESTER—A 5 mg to 50 ton range multitester that performs tensile, pressure, and bending tests on a wide variety of substances has been announced by **J. W. Fecker, Dept. S/A, 6592 Hamilton Ave., Pittsburgh 6, Penna.** The linear deformation speed of the unit may be varied from 1 to 1000 mm/min. It features exchangeable heads that are frictionless and without hysteresis. For routine work, deformation is indicated by a change in distance between sample clamps with ratios of 5:1, 1:1, or 1:5. These ratios can be extended from 10:1 to 1000:1 The unit operates on 220 volts, 60 cps. It measures 10.5 x 5.0 x 2.3 ft.

No. 345 on Reader Service Card

DATA FILE

FACILITIES—The facilities of the **Photo-Optical Division of Consolidated Systems Corp., Dept. S/A, 1725 S. Peck Rd., Monrovia, Calif.** are described in a 15-page illustrated brochure. Included are information about their Bell & Howell cameras, spectron optics, and photo-optical systems.

No. 335 on Reader Service Card

RECOVERY—A booklet has been issued by **Space Recovery Systems, Inc., Dept. S/A, 140 Oregon St., El Segundo, Calif.,** describing their facilities and capabilities in the field of recovery systems. The booklet illustrates some typical projects in this area.

No. 336 on Reader Service Card

PRESSURE CELL—Product data sheet 4381 describes the SR-4 pressure cell being manufactured by **Baldwin-Lima-Hamilton Corp., Dept. S/A, Waltham 54, Mass.** In addition to a photo and dimension drawing, it includes a description and complete specifications on the unit.

No. 337 on Reader Service Card

CONTROLS—A design manual on valve remote control systems has been issued by **Stow Mfg. Co., Dept. S/A, Binghampton, N.Y.** This illustrated Bulletin 618 includes data on the selection of flexible shafts, dimensional data and typical shafting arrangements. Data are also included on rigid rod controls and gear boxes.

No. 346 on Reader Service Card

RELAY — High voltage transfer relay RVS-1 is covered in a data sheet issued by **Resitron Laboratories, Inc., Dept. S/A, 2908 Nebraska Ave., Santa Monica, Calif.** It gives a brief description, including applications and detailed specifications. The sheet also includes brief writeups on other Resitron products.

No. 338 on Reader Service Card

TRANSDUCER — "3S-G Silicon Semiconductor Strain Gage Pressure Transducer" is the title of an 8-page, illustrated brochure recently issued by **Fairchild Controls Corp., Dept. S/A, 225 Park Ave., Hicksville, N.Y.** The brochure contains design and performance data on airborne and ruggedized versions of the unit. Photographs, line drawings, schematics, and a cutaway view are given.

No. 339 on Reader Service Card

VIEWERS—Viewers, film readers, and interpretation consoles are all described in an illustrated booklet now available from **Itek Laboratories, Dept. S/A, Lexington 73, Mass.** For each unit, a photograph, description, and specifications are included, and specifications are included. Specs include such items as dimensions, resolution, magnification, capacity, speeds, and power requirements.

No. 340 on Reader Service Card

VIBRATION FACILITY—Their unique vibration facility for testing solid propellant rocket motors under controlled temperature conditions is described in a brochure issued by **Wyle Laboratories, Dept. S/A, El Segundo, Calif.** The equipment, its instrumentation for sensing and recording data, and its test monitoring gear are all described in this 25-page brochure.

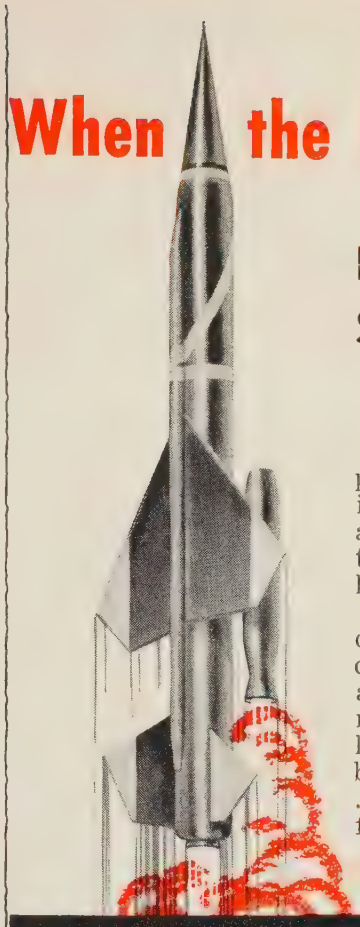
No. 341 on Reader Service Card

TV CAMERA — Model CC420 transistorized TV camera is described in a pamphlet issued by **Hallamore Electronics Div., Dept. S/A, 714 N. Brookhurst St., Anaheim, Calif.** It gives operational characteristics, environmental data, physical characteristics, and electrical performance. Dimension and assembly drawings are also given.

No. 342 on Reader Service Card

GSE — A 24-page illustrated booklet describing their programmable automatic comparator for use in shop, factory, or flight line, is now available from **General Electric Co., Dept. S/A, French Rd., Utica, N.Y.** It gives a technical description, including schematics and block diagrms. A discussion of tape preparations and a physical description are also included.

No. 343 on Reader Service Card



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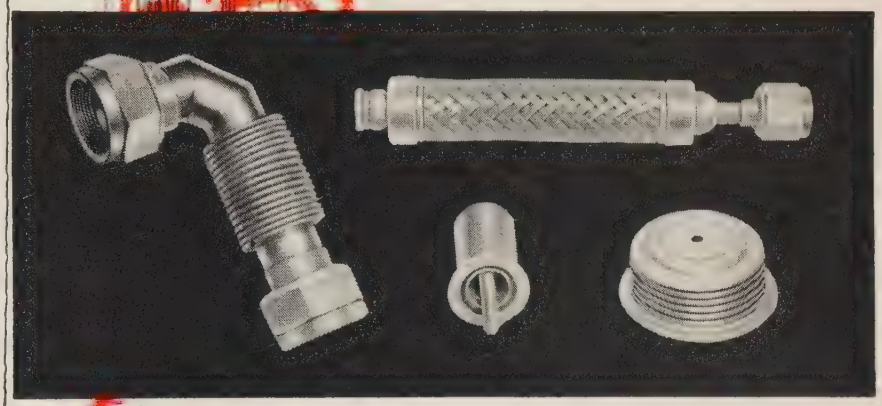

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No. 110 on Reader Service Card

DESIGN DEVELOPMENTS

For more details on the equipment, processes, and facilities described in this section

INERTIAL GUIDANCE LINE TESTED FOR YEARS, MEETS AF SPECS

A preferred line of simple inertial guidance components featuring high accuracy and reliability as well as low cost has been announced by American Bosch Arma Corp., Roosevelt Field, Garden City, N.Y. These components have been evolved over a period of years and are in volume production for use in Arma systems and for other applications. The detailed evaluation of the units has included life tests running several years; vibration, shock, and temperature cycling; centrifuge tests; sled tests; and ICBM flight tests. The performance of the units is well within the requirements of the Air Force, according to Arma.

Among the components is a vibrating-string accelerometer that is used in all Arma inertial systems. The complete absence of moving parts, a simple mechanical structure, and minimal electronics contribute to the long life and low cost of the unit. The accelerometer is based on a pair of matched, vibrating magnetic reeds whose free ends are mass-loaded and elastically coupled so that acceleration along the axis causes equal and opposite changes in their natural frequencies of vibration. Vibration is maintained by regeneration of the voltage induced in the vibrating reeds. Special amplifiers feed back current to provide the energy to sustain oscillation. The accumulated count of the difference frequency is a measure of velocity change (which is why the unit is often referred to as a "velocity meter").

Another component of this line is Arma's two-axis gyro, a neutrally floated buoyant unit. Because of the two-axis design, only two gyros are required in a platform to provide complete stabilization in space. In addition, a redundant axis is available to provide extra accuracy and reliability.

The principal gyro element is the wheel, which rotates inside a hermetically sealed ball floating in neutral equilibrium in the fluid inside the gyro housing. A buoyant gimbal ring encircles the ball float, which is centered within the gimbal and the housing by thin, elastic centering members. These are maintained at zero angle of twist by the platform servos. This arrangement results in a frictionless suspension and eliminates all motion of the float relative to the housing under high shock loads, so that very high accuracies are maintained.

Because of the two-degree-of-freedom design, a single gyro provides platform stabilization signals about two axes. The pickoff is built as a two-axis device, with two windings at right angles to each other, each capable of sensing one of the two motions.

Arma has also developed complete inertial platforms. The most recent of these is an integral assembly of an all-attitude platform with its electronics and housing. Optionally, an integral star-tracker may be added to the basic complement of three vibrating-string accelerometers, two two-degree-of-freedom gyros, four servo drives, and the system electronics. The major components are located for maximum accessibility. **63**

TV Comparator Magnifies up to 300X

A television comparator for the examination and precise measurement of miniature solid objects at magnifications of up to 300 was exhibited for the first time at Wescon by General Precision, Inc., GPL Div., 63 Bedford Rd., Pleasantville, N.Y. It is believed to be the first of its kind.

A closed-circuit television system lets an operator inspect and examine, in minute detail, components like transistors, resistors, diodes, microminiature wafers, instrument and watch parts, and subassemblies. The unit can also be used to examine and study live biological specimens and standard lab slides.

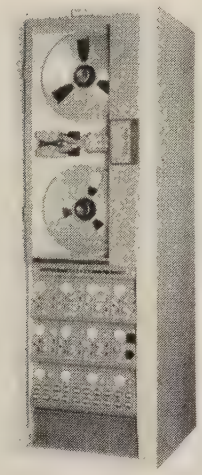
Using an aircraft-type control stick, an operator can position the image on the screen and change its magnification through the entire range without loss of focus.

A simple accessory to the television comparator permits precise measurement of an object or any portion of it at three times the magnification of conventional comparators. **64**

Electronics

write in item numbers on Reader Service Card

Operational Predetection Recorder for Polaris



The first operational predetection recording system for the acquisition of Polaris missile program data is now in use in the Navy. The video-band recorder-reproducer of the system is the CM-100, developed by Mincom Div., Minnesota Mining & Manufacturing Co., 2049 S. Barrington Ave., Los Angeles, Calif. Only an antenna and a standard receiver with the necessary converters has to be added to the CM-100 make up the complete predetection recording system.

The single-rack CM-100s used in the Polaris program have seven tracks and a frequency response from 400 cps to 1.2 mc (with the ½-in. tape traveling at 120 ips). A selection of six speeds ranging from 7½ to 120 ips provides a speed reduction ratio of 16.

Predetection recording techniques offer a number of advantages over other recording methods. Greater system reliability is achieved because the original data are recorded directly from the IF carrier. The best detection method can be used for processing each signal, because the information is stored in a predetected state.

Other advantages of predetection recording include a high degree of immunity to tape dropouts and the fact that an actual flight can be simulated on playback in checkouts of the complete ground station and its equipment. Furthermore, a number of copies can be made of the prime data tapes with little or no degradation of the data in reproduction. **65**

TELEMETRY SYSTEM — A video telemetry system for transmitting real-time television over a mobile link has been developed by **TAPCO Div., Thompson Ramo Wooldridge, Inc., Dept. S/A, 23555 Euclid Ave., Cleveland 17, O.** The system includes a wide band, FM, UHF transmitter and receiver. Carrier frequency is 882 mc—video response is substantially flat from 30 cps to 4.5 mc. Transmitter specs include: input power-245 watts; input voltage-28 volts dc; RF output-20 watts nominal; deviation-8 mc. Receiver specs include: input power-340 watts; input voltage-117 volts ac; frequency stability -0.05 percent of adjustmant carrier frequency; bandwidth-10 mcs to the 4 db points; noise factor-9 db.

No. 349 on Reader Service Card

ANTENNA MOUNT — Weighing less than 1000 lb, this model 28 antenna for shipboard and ground applications is now available from **Temec, Inc., Dept. S/A, 7833 Haskell Ave., Van Nuys, Calif.** Special features include gyro stabilization, a complete solid state ac servo system, and automatic beam crossover switching from 3 to 9 db. Production models use a 5-foot reflector for the 5 kmc range. The system has slew rates of 36 deg/sec and accelerations of 130 deg/sec/sec. One-quarter hp servo motors are used for remote stowing. An azimuth rotation of 170 degrees with hydraulic stops, is currently available, but slip rings may be provided to facilitate continuous rotation, if desired. Dynamic braking protects the structure from shock loading.

No. 350 on Reader Service Card

YOU PICK THE ALLOYS

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Low Alloy Series, including: 4100, 4300, 8600

400 Series Stainless, including: 410, 416, 420, 431, 440

300 Series Stainless, including: 302, 303, 304, 310, 316, 347

PH Alloys, 17-4, AM355

Hastelloys

Cobalt-base Alloys, HS3, HS6, HS30, HS151, WI-52, X-40, AMS-5382, AMS-5385

VACUUM MELTED

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Udimet 700
R-235D
Nicrotung
SM302
DCM
Oxy-Free Copper

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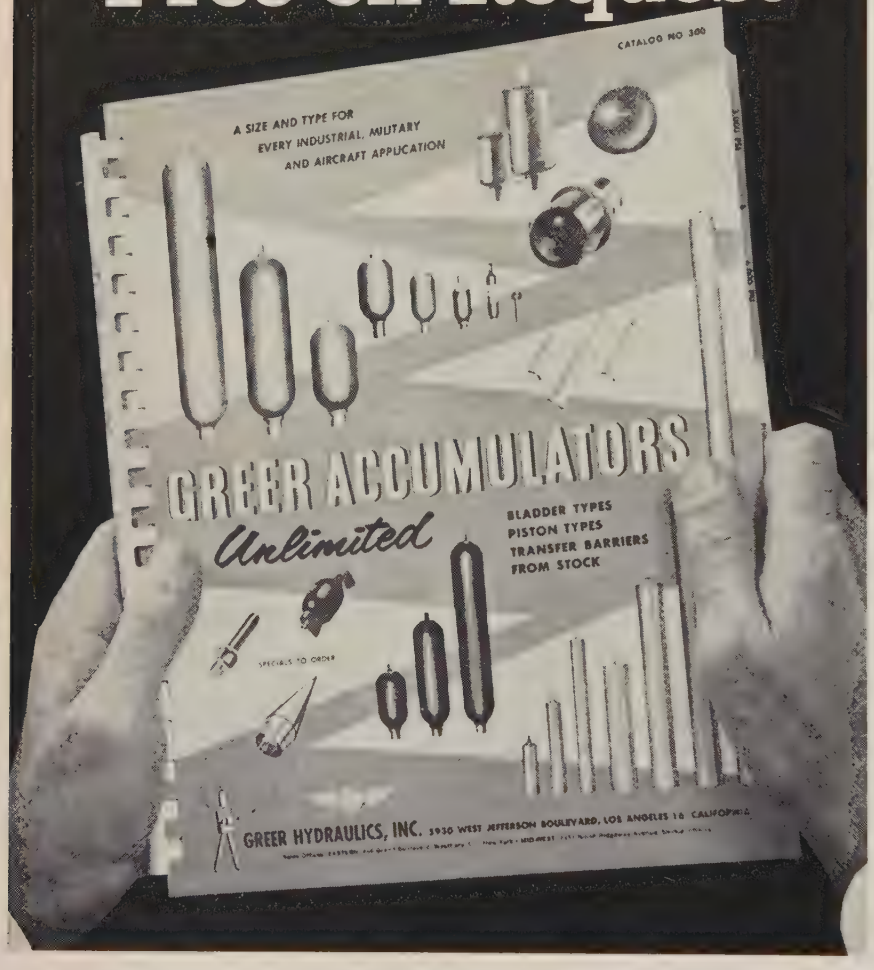
No. 111 on Reader Service Card

FOR DESIGN ENGINEERS:

Valuable Accumulator Handbook-Catalog Free on Request



Circuits, Curves and Complete Technical Information on Bladder-Type and Piston-Type Accumulators Available from Stock

More than 113 pages are devoted exclusively to hydro-pneumatic accumulator principles, uses in hydraulic circuits, designs and specifications in the new Greer "Accumulators Unlimited" handbook-catalog. Complete design information extensively covers: *Bladder Accumulators*—3,000 psi and 6,000 psi series—more than 30 standard off-the-shelf models in sizes from 1½ cubic inches to 10 gallons including transfer barriers; *Piston Accumulators*—nine sizes, 10 cubic inches to 10 gallons, available from stock in a 3,000 psi series, other sizes available to 30 gallons. This valuable "Accumulators Unlimited" handbook-catalog is available to design engineers without obligation. Contact your Greer representative.

PRODUCT SALES DEPARTMENT
GREER HYDRAULICS, INC.
5930 West Jefferson Blvd., Los Angeles 16, Calif.
Eastern: 496 Grand Blvd., Westbury, L.I., N.Y. • **Mid-West:** 7331 N. Ridgeway Ave., Skokie, Ill.

No. 112 on Reader Service Card

PHOTOTUBE SURFACES—The development and application of trialkali photo surfaces for a line of multiplier phototubes is announced by **Allen B. DuMont Laboratories, Dept. S/A, 750 Bloomfield Ave., Clifton, N.J.** The surface is said to have high sensitivity to the white light spectrum. This is primarily due to extension of response into the red region of the spectrum. Peak sensitivity is maintained at about 4200 Angstrom units, with 50 percent of peak response maintained at 7000 Angstrom units. Specs include cathode sensitivity in the range of 120 to 150 microamperes per lumen, with current amplification factors between 200,000 and 300,000 at 1800 volts.

No. 351 on Reader Service Card

PULSE TRANSFORMER—The PIP series of transistor pulse transformers has been announced by **United Transformer Corp., Dept. S/A, 150 Varick St., New York 13, N. Y.** These units have a ratio of 4:4:1, and are individually checked and adjusted in a transistor test circuit. Characteristic parameter ranges are 0.05 to 10 microsecond pulse width, rise time of 0.018 to 0.4 microseconds, and input and output impedances of 50 to 200 ohms.

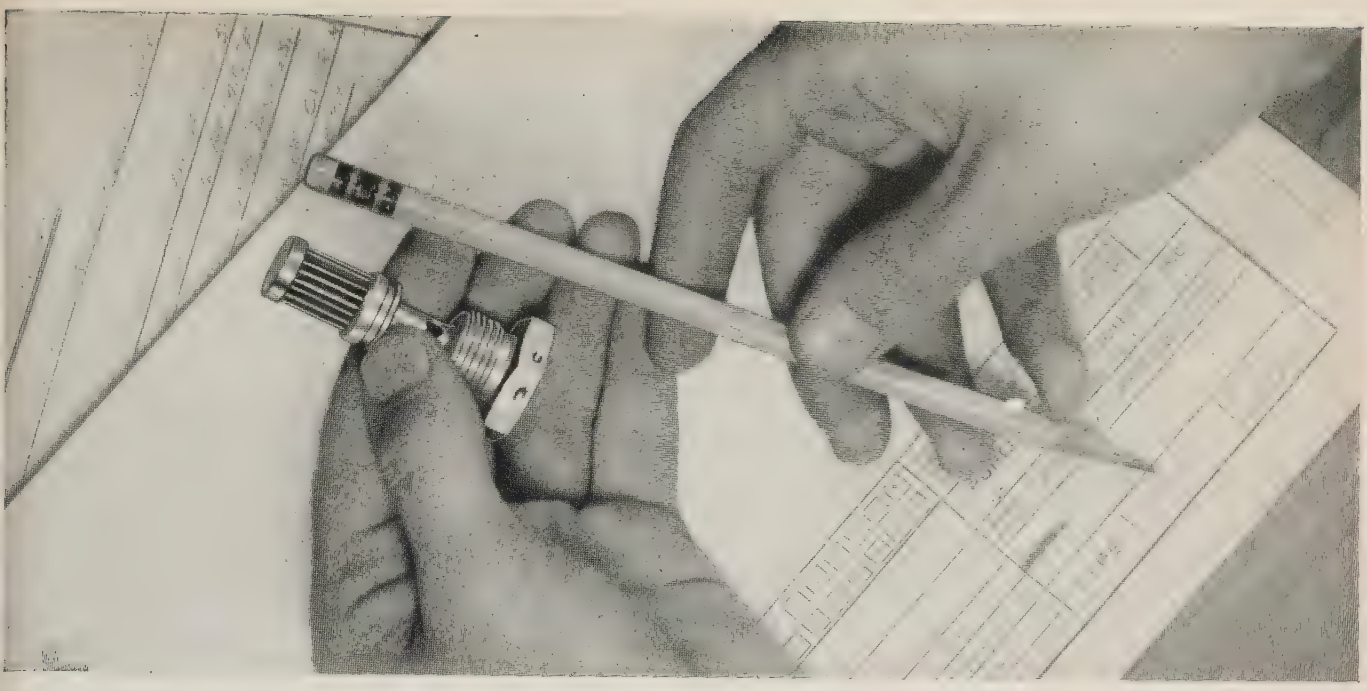
No. 352 on Reader Service Card

RECORDER—A desk-top size unit that monitors and records the efficiency of up to 40 production or data processing machines is now being marketed by **Electronics Associates, Inc., Dept. S/A, Long Branch, N.J.** Basic units of the recorder are a rotating drum, an inkless chart with 40 vertical bars or channels, and a stylus. Every 20 seconds, the recorder samples and records the performance of the data processors being monitored. If the processor is operating, that fact is recorded with a short line in the appropriate channel. Lines do not appear if the machine is idle. The recorders are available with charting time of 9, 17, or 24 hours per chart.

No. 353 on Reader Service Card

MICRO DIODE — This 1000-volt micro diode achieves reverse leakages less than 25 millimicroamps at 80 percent V_s says **MicroSemiconductor Corp., Dept. S/A, 11250 Playa Court, Culver City, Calif.** Capable of being connected in series for potentials in excess of 30,000 volts, a typical 10-00-volt unit will fit an envelope size of 0.140 x 0.500 x 0.550 in., with a leakage current of 2 microamps at 100 deg C, at the rated PIV. Special 1500-volt models are available with conductances of 1 amp at 1 volt DC.

No. 354 on Reader Service Card



Miniaturized cavity-type filter packs 4.2 square inches of filtering area into 1" x 9/16" element

Purolator develops thumb-nail size element to protect hydraulic control circuits on Army's Hawk Missile mobile launcher.

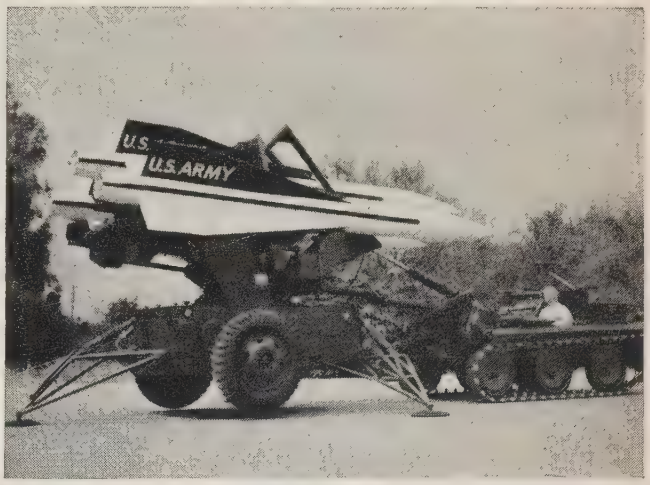
How small can you make an element that must filter 2 gpm hydraulic oil at 2500 psi at any temperature within a 315° range? Purolator's new miniature cavity-type hydraulic filter is the best answer to date. Here's why:

4.2 square inches of convoluted stainless steel wire cloth are packed into this miniature filter. This element, which weighs 0.25 ounces, filters two gallons per minute of hydraulic oil, at temperatures ranging from —40° to + 275° F. The element will withstand 2500 psi differential pressure without collapsing.

The element is made up of a total of 1/5-mile of stainless steel wire, woven into wire cloth and convoluted to extend filtration area. This element will remove 98% of all particles whose two smallest dimensions are larger than 10 microns, and 100% of all particles measuring 25 microns or more.

The picture at the top of the page shows you the complete filter assembly, ready for installation in the hydraulic control system. The overall length of the unit is 2 1/32"; maximum overall diameter is 1". Total weight is slightly over 1 ounce. Designed as a cavity-type unit, the filter is installed simply by screwing it into the hydraulic system so the filter element intercepts oil flow. The element can be removed, cleaned and replaced without special tools.

The picture at right shows the mobile launching platform for the Hawk Missile. The compactness and mobility of the



launcher, and the probability that it would be subjected to severe jolting, made it necessary to specify as small a filter as possible, and one that could be integrated with the rest of the system for maximum simplicity and durability.

The Purolator engineers who developed this new miniature cavity-type filter are available now to design a filter to meet your specifications. Simply contact Purolator Products, Inc., Department 3096, Rahway, New Jersey.

Filtration for Every Known Fluid **PUROLATOR**

PRODUCTS, INC.

RAHWAY, NEW JERSEY, AND TORONTO, ONTARIO, CANADA

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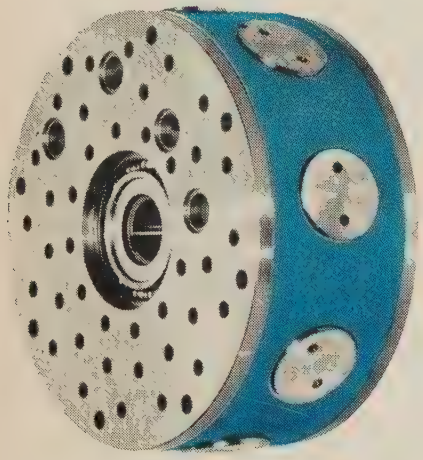
In another week this motor will complete one revolution



Why so slow?

Because tracking radar–
Radio telescopes–
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All need this servo motor

. . . that will rev up to 500 rpm and throttle down to 1/60,000 rpm . . . accelerate up to 40,000 radians per sec. per sec. . . . work at sensible 500 psi . . . stay rock stiff (no gears, no backlash).

Cimtrol's unique Acradrive
22 cu. in., 8 cylinder radial
Hydraulic Servo Motor

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The Cincinnati Milling Machine Co.
Cincinnati 9, Ohio

CIMTROL

No. 114 on Reader Service Card

RESISTORS—High wattage resistors having ratings of 2000 watts, which have operated at 1000 deg F temperatures are being manufactured by **Industrial Heater Co., Dept. S/A, 760 Esplanade, San Jacinto, Calif.** The all-metal and ceramic construction provides for stable operation over wide temperature ranges, and is in accord with Mil-Std-202 requirements. These high wattage units have been used to absorb unwanted peaks in energy deliveries on missile auxiliary power systems.

No. 355 on Reader Service Card

SIGNAL GENERATOR—This high frequency signal generator features a unique push-button attenuator system for fast signal light readout, according to **Borg-Warner Controls, Dept. S/A, Santa Ana, Calif.** Covering a frequency range from 50 kc to 65 mc, this model G-101 also incorporates an automatic level control circuit which maintains the indicated level to ±1 db, regardless of frequency output or percent of modulation. The push-botton feature provides a step-by-step reduction of the rf output signal amplitude from 1.0 volts into a 50-ohm load. Attenuation through a range of −120 to 10 dbm is provided.

No. 356 on Reader Service Card

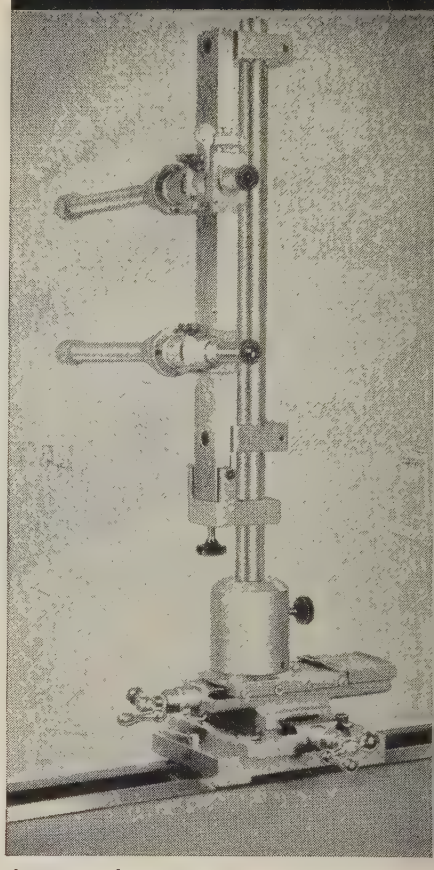
MAGNETRON— A voltage-tunable magnetron, having minimum CW power of 10 watts across a frequency range of 2.5 to 3.5 Gc, has been developed by **General Electric Co. Dept. S/A, Schenectady, N.Y.** This ZM-6019 model can sweep its entire operating band in less than a nanosecond. Average anode current is 10 to 20 milliamps. In typical operations, its anode voltage is 2000 volts at 3 Gc. Filament current is 3 amps, and filament voltage is about 2.5 volts. Tuning rate is 1.5 mc per volt. The tube operates at a maximum voltage of 2500 volts, maximum anode current of 30 milliamps, and maximum filament current of 3.2 amperes.

No. 357 on Reader Service Card

VARACTORS—High cutoff frequency gallium arsenide varactors with a working voltage of 30 volts are now being produced by **Micro States Electronics Corp., Dept. S/A, Murray Hill, N.J.** These diffused junction mesa structures, in coaxial pin packages, are said to make power disposition of 1 watt practical. Units are available with zero bias capacitance range of 0.2 to 1.1 micromicrofarads and a range of cutoff frequencies from 40 to 120 kmc. Other units have a capacitance range of 3 to 6 micromicrofarads and cutoff frequencies of 10-20-60 Kmc. A third type has capacitance ranges of 6 to 10 micromicrofarads, with 10-20-40 Kmc cutoff frequencies.

No. 358 on Reader Service Card

INSTRUMENTS TO MEASURE LINEAR DIMENSIONAL CHANGES



Instrument shown measures specimens 2" to 12" long. Total range 0.040", reading to 0.00001". Has relay lenses for 8" working distance. Adjustment in 3 axes. Mounted on lathe bed type ways for use with multiple specimen setups. **This instrument is representative of a line especially suited to measurements at high temperatures.**

For help with your precision measuring problems, call on Gaertner experience

Your measuring problems may very well be nicely solved with optical instrumentation. Gaertner Scientific Corporation can probably recommend a standard or modified instrument to meet your particular needs. If necessary, we are fully equipped to design and build special instrumentation.

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Tailoring protection for a "hot-spot"

JOHNS-MANVILLE TECHNICIANS CREATE MANY COMPLEX FORMS FOR SERVICE IN CRITICAL MISSILE AND AIRCRAFT APPLICATIONS

This expert operator is stitching a rocket exhaust tube seal, designed to insure top sealing efficiency under conditions of flame and searing heat. It is just one of the many J-M protective parts which are now successfully taking the hazards out of "hot-spots" where flame, temperatures or corrosives create critical conditions.

In J-M's newly-formed Custom Parts Department, skilled technicians and machine operators custom-tailor these complex forms to your exact specifications. Employing every modern technique, they work with virtually any material you can name—asbestos fabrics, elastomers, metals, refractory fibers and many others. J-M craftsmen have successfully solved hundreds of difficult sealing and motion control problems that at first seemed impossible.

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No. 166 on Reader Service Card

NEW ADDITIONS

to the Allegheny Ludlum High Strength and High Temperature Steels

AL REFERENCE DATA

Compiled by
ALLEGHENY LUDLUM STEEL CORPORATION
Oliver Building • Pittsburgh 22, Pennsylvania

	Alloy Name	NOMINAL CHEMICAL COMPOSITION										
		C	Mn	Cr	Ni	Co	Mo	W	Ti	Al	B	Fe	Others
Fe-Base	19-9DL	.30	1.0	19	9	..	1.4	1.3	.3	...	...	66	.4 Cb
	19-9DX	.30	1.0	19	9	..	1.6	1.3	.6	...	...	66	.....
	AF-71	.30	18	12.5	...	..	3	...	...	...	.2	73	.2N, .9V
	A-286	.05	1.4	15	26	..	1.25	...	2.2	.2	.003	54	.3 V
	Discaloy	.05	.6	13	26	..	3	...	2	.2	...	54	.....
	G-192	.60	8.5	22	...	..	....	...	...	...	...	69	.35 N
	V-57	.06	.25	15	26	..	1.3	...	3	.2	.008	54	.2 V
Fe-Ni	D-979	.05	.6	15	45	..	4	4	3	1	.01	27	.....
	AL 901	.05	.25	13	43	..	6	...	2.9	.2	.015	35	.03 Zr
Ni-Base	Waspaloy	.05	.3	19	56	14	4	...	3.0	1.3	.005	1	.....
	M-252	.15	.5	19	55	10	10	...	2.5	1	.005	2	.....
	R41	.10	.3	19	53	11	10	...	3.2	1.6	.005	2	.....
Co-Cr-Fe-Ni	S-590	.43	1.2	20	20	20	4	4	...	...	...	29	4 Cb
	N-155	.15	1.5	21	20	20	3	2.5	...	...	...	32	1 Cb
Co-Base	S-816	.40	1.2	20	20	44	4	4	...	...	...	3	4 Cb
	V-36	.30	1	25	20	42	4	2	...	...	...	3	2 Cb
	L-605	.15	1.5	20	10	53	....	15	...	...	...	...	.....

A number of the names listed above are tradenames of companies other than Allegheny Ludlum Steel Corporation

AL REFERENCE DATA

Compiled by
ALLEGHENY LUDLUM STEEL CORPORATION
Oliver Building • Pittsburgh 22, Pennsylvania

	Alloy Name	Density lb/in.³	100-Hr. Rupture Strength at (X 1000 Psi)				Short Time Properties					
			1200F	1350F	1500F	1600F	Room Temperature TS	.2YS	Elong. %	1200 F TS	.2YS	Elong. %
Fe-Base	19-9DL	.287	52	28	17	...	118	69	55	75	37	33
	19-9DX	.287	52	28	17	...	118	69	55	75	37	33
	AF-71	.280	69	40	22	...	150	110	30	90	77	43
	A-286	.286	63	35	15	...	152	110	25	115	87	25
	Discaloy	.288	55	32	15	...	147	92	20	100	77	18
	G-192	.278	42	27	15	...	148	85	55	92	37	15
	V-57	.286	75	40	15	...	172	119	24	129	108	22
Fe-Ni	D-979	.296	94	63	35	21	200	143	18	157	123	17
	AL 901	.294	90	60	20	...	175	125	15	145	110	20
Ni-Base	Waspaloy	.294	98	65	39	24	185	130	28	160	120	22
	M-252	.298	95	62	35	20	180	122	16	155	110	17
	R 41	.296	100	67	44	28	200	150	15	160	130	10
Co-Cr Fe-Ni	S-590	.301	50	32	22	13	140	75	20	97	70	25
	N-155	.297	50	31	18	12	119	58	40	80	43	55
Co-Base	S-816	.313	60	38	25	16	140	72	35	115	55	27
	V-36	.303	64	35	25	18	145	67	55	95	40	28
	L-605	.330	70	43	24	15	150	70	50	98	48	28

Properties listed above are typical, and should not be used as specification minima.

Mar-Aging Steels...with yields over 250,000 psi PLUS toughness!

Looking for "special" properties even in the special steels? Take a look at the Mar-Aging Steels, a brand new group of high alloy, precipitation-hardening steels offering unmatched toughness and the strength of the best contemporary steels. Here are a few interesting properties ... yield strengths exceeding 250,000 psi ... notched tensile strengths over 400,000 psi ... and the ability to maintain ductile properties below −80 F.

Discovered by International Nickel Company, developed and being produced by Allegheny Ludlum, the Mar-Aging steels achieve their high strength by means of an extremely simple heat treatment. Remarkably resistant to crack propagation, the Mar-Aging Steels are easily machinable, easy to weld, and possess unusually low work-hardening characteristics. Available in all product forms, the Mar-Aging Steels may be air melted, or vacuum melted for maximum notch toughness and transverse ductility.

Together with A-L's family of famous stainless steels (all grades — all mill forms), low alloy-high strength steels, tool steels, bearing steels, and high temperature steels and alloys, the Mar-Aging Steels make the Allegheny Ludlum product line one of the most comprehensive offered to the aircraft and missile industries. And to assist in applying this family of steels, A-L offers customer contact service at any level in your organization, including in-plant teamwork with your specialists on your problems. Add the support of the A-L research organization, and technical literature written in *your* language, and you have the famous Allegheny Ludlum service.

NOMINAL COMPOSITION OF MAR-AGING STEELS

	C	Ni	Co	Mo	Ti	Al	Cb
AL 25 Ni (250)	.01	25	..	..	1.4	.2	.5
AL 20 Ni (250)	.01	20	..	..	1.4	.2	.5
AL 18 Ni Co Mo (250)	.01	18	7	5	.4	.1	..
AL 18 Ni Co Mo (300)	.01	18	9	5	.6	.1	..

TYPICAL MECHANICAL PROPERTIES OF MAR-AGING STEELS

PRODUCTS	.2 YS (X 1000 psi)	UTS (X 1000 psi)	Elong. %	RA %	Notch TS / Smooth TS
BARS (Heat treated)					
AL 25 Ni (250)	250	265	12	50	1.1
AL 20 Ni (250)	250	265	12	55	1.3
AL 18 Ni Co Mo (250)	250	265	10	50	1.5
AL 18 Ni Co Mo (300)	300	305	12	55	1.4
SHEETS (Cold rolled and aged)					
AL 25 Ni (250)	250	270	5	..	.7
AL 20 Ni (250)	260	270	4	..	.7
AL 18 Ni Co Mo (250)	285	290	4	..	.9
AL 18 Ni Co Mo (300)	300	310	3	..	.8

3803

ALLEGHENY LUDLUM

NEW A-L LITERATURE

A new series of technical booklets on A-L High Temperature Alloys is yours for the asking. Each is packed with data to assist design engineers and procurement specialists in selecting materials for any high strength-high temperature application.

And be sure to get your request in early for the new Data Sheet on Mar-Aging Steels. Contact your local A-L Representative, today. Or write: Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa. Address: Dept. MID 6.

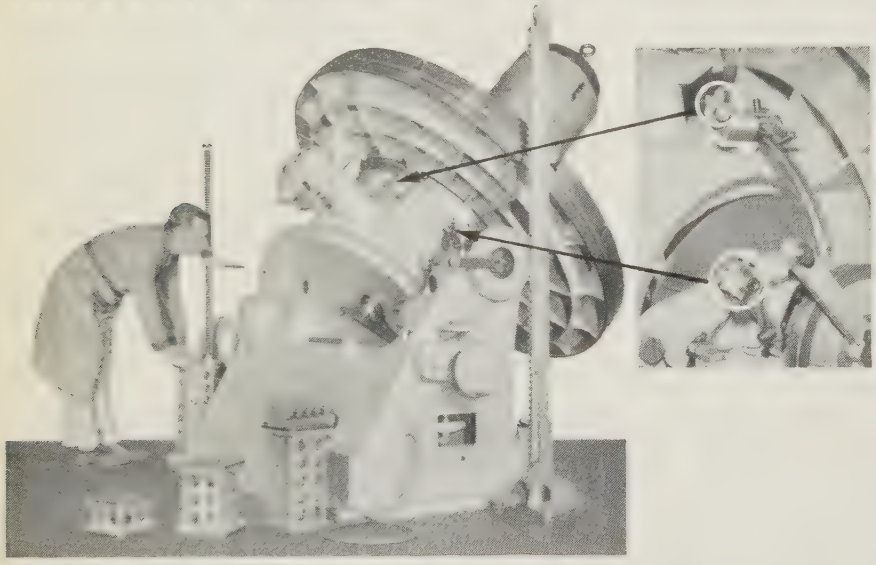
GERMANIUM TRANSISTOR — This series of germanium ADMT has been introduced by **Texas Instruments, Inc., Dept. S/A, P.O. Box 5012, Dallas 22, Tex.**, for application in AM-FM receivers, auto receivers, citizen band transceivers, and amateur radio equipment. All of these units are reported to feature excellent high frequency current gain, low output capacity, and a typical output impedance greater than 1 M. With an alpha cutoff typically at 200 mc, they are said to exhibit very low noise figures, and rf amplifier units have typical leakage current of less than 1 microamp. Texas indicates that the line is priced economically for consumer product markets.

No. 359 on Reader Service Card

PARAMETRIC AMPLIFIER — This model PA—C—3 parametric amplifier is a reflection type, negative resistance, low noise, rf unit, being manufactured by **Aeronca Mfg. Corp., Dept. S/A, P.O. Box 517, Baltimore 3, Md.** Operating frequency is 5.25 to 6.00 kmc, tunable over a 10 percent band. Noise figure is 3 db and, under most conditions, 20 db of gain and 25 mc bandwidth can be achieved with pump powers between 40 and 70 milliwatts. Cain-bandwidth product remains constant between 15 and 27 db gain. The unit is less than 0.3 cu ft, and weighs eight lb, not including pump power supply.

No. 360 on Reader Service Card

THROUGH THESE MICROSCOPES . . .



. . . positioning with 5 second accuracy!

(2 second accuracies available in ROTAB sizes from 12″ to 48″)

Rotary table positioning with 5 second accuracy? Amazing! And when you recall that there are 1,296,000 seconds in any circle, 5 second accuracy is indeed amazing, but *true* . . . with ROTAB tiltable rotary tables. For by incorporating optical measuring systems into ROTAB design, full 360° radial positioning, 90° angular settings are easily achieved with this fine degree of precision . . . and repeat settings within one second of arc are standard procedure!

Microscopic accuracy is just one unique ROTAB feature. In addition, motor powered rotating and tilting, easy-to-use portable controls, horizontal loading vastly improve efficiency . . . to a point, in fact, where 50% savings in set-up time *alone* are not unusual. You can use ROTAB, moreover, for inspection and quality control operations or for tool room machining. In a nutshell, ROTAB gives you precision positioning, cost-cutting efficiency and a wide range of application versatility. Ask about ROTAB today!

FREE! Catalog containing detailed information on complete ROTAB line, from 12″ to 84″ faceplate sizes. Yours for the asking . . . write today.

MP MACHINE PRODUCTS CORPORATION
6771 E. McNICHOLS ROAD • DETROIT 12, MICHIGAN

No. 146 on Reader Service Card

No. 117 on Reader Service Card

WIREWOUND RESISTORS — A line of miniature precision wire wound resistors designated Squaristors, is being offered by **General Resistance Inc., Dept. S/A, 1 Northern Blvd., Great Neck, N.Y.** Available from 1 to 1,200,000 ohms, their ⅛ x ¼ x ¼ size permits uniform stacking and high density packaging. Temperature coefficients are as low as ±3 ppm/deg C from 0 to 100 deg C and ±5 ppm/deg C from −55 to 125 deg C. Normal temperature coefficient is ±10 ppm/deg C.

No. 361 on Reader Service Card

POWER SUPPLIES—A series of rugged, solid state, pulsed, keep-alive power supplies has been announced by **Burmac Electronics Co., Inc., Dept. S/A, 142 S. Long Beach Rd., Rockville Center, N.Y.** A typical model operates on 180 volts dc, and produces two output pulses of 35 microsecond duration. The main pulse varies from 700 to 900 volts peak and the second pulse, for syncing or keying, is fixed at 60 volts peak into a 100-ohm load. This hermetically sealed, epoxy filled unit measures 1-⅞ x 3-½ x 2 in.

No. 362 on Reader Service Card

RECTIFIERS—Two new series of silicon controlled rectifiers featuring microsecond switching speeds and a firing current of 5 ma at 100 deg C, are now available from **International Rectifier Corp., Dept. S/A, 233 Kansas St., El Segundo, Calif.** One series is rated at 10 amperes over a PRV range of 25 to 400 volts. The second series is rated at 16 amperes over the same PRV range. Both series can withstand a peak 1-cycle surge current of up to 150 amperes.

No. 363 on Reader Service Card

TRANSFORMERS—Miniature transformers with weldable leads to permit high reliability welded connection in high density electronic assemblies are now available from **Microtran Co., Inc., Dept. S/A, 145 E. Mineola Ave., Valley Stream, N.Y.** According to the company, special gold plated nickel iron alloy lead wire is used for the weld joints.

No. 364 on Reader Service Card

WAVEGUIDE DEVICES—The ability to fabricate simple and complex bends in mm-band circular waveguides for operation in the low loss TE_{01} mode has been announced by **TRG, Inc., Dept. S/A, 9 Union Square, Somerville, Mass.** These bends are made by first corrugating the inside of lengths of straight copper waveguide, and then bending them to the desired shape. A typical 90-degree bend at 70 Kmc has a 30-in. radius and a 0.3 db loss.

No. 365 on Reader Service Card

COOLING UNIT — The development of the F-3DC Frigistor, a thermoelectric cooling unit of high pumping capacity, has been announced by **General Thermoelectric Corp., Dept. S/A, P.O. Box 253, Princeton, N.J.** It consists of three couples, the cold sides of which extract heat from the component case. The heat is pumped out the other side of the cooler and rejected. The unit provides cooling up to 17 amps current. Operating voltage is only 0.3 volt.

No. 366 on Reader Service Card

MAGNETRON— Type ZM-6021 is a bowl-magnet design, voltage-tunable magnetron that has been developed by **General Electric Co., Dept. S/A, Schenectady 5, N.Y.** The unit covers L-band in a rated range of 1 to 2.3 Gc, at a minimum CW power of 1 watt. It operates at a maximum anode voltage of 2000 volts, and is voltage-tunable over all, or a portion, of its frequency range at a rate of 1.2 mc per volt. GE also has available the ZM-6014 bowl-magnet design for the UHF range and the Z-5337 for the S-band range.

No. 367 on Reader Service Card

DATA FILE

POWER SUPPLIES—A 16-page catalog describing a line of power supplies if offered by **NJE Corp., Dept. S/A, Kenilworth, N. J.** High voltage units, transistorized and dc output supplies are presented.

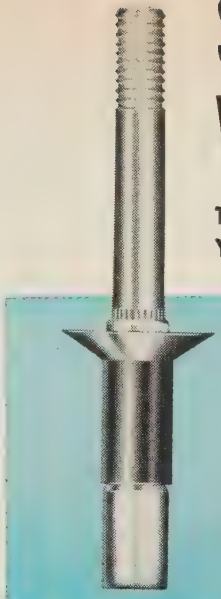
No. 368 on Reader Service Card

INSTRUMENTS—A 16-page brochure describing a line of measuring instruments for electronic and missile applications is available from **Physical Sciences Corp., Dept. S/A, 389 No. Fair Oaks Ave., Pasadena, Calif.** Presented are full level probes, strain gages, dc transducer monitors and digital millivoltmeters.

No. 369 on Reader Service Card

SOLID RIVET STRENGTH WITH BLIND RIVETS

THE CHERRYLOCK TEAM — A Blind Rivet for Your Difficult Solid Rivet Applications

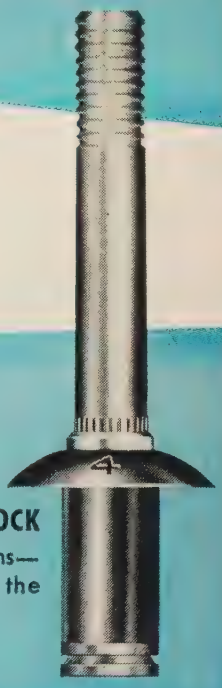


STANDARD CHERRYLOCK

Top performance through the entire range of diameters and materials

ONLY THE CHERRYLOCK TEAM GIVES YOU ALL THESE ADVANTAGES

Mechanically Locked Stem • Flush Fracture (No Stem Trimming) • Positive Clamp-Up • Full Grip Range • Complete Hole Fill • Positive Visual Inspection (Grip Length Marked on Head)



BULBED CHERRYLOCK

Ideal for thin sheet and double-dimple applications—extremely large head—the shorter the grip, the stronger the rivet

A-286 Stainless Steel • Monel • Aluminum

The Cherrylock* Team—The Standard Cherrylock and the Bulbed Cherrylock—offers a blind rivet that installs and performs like a solid rivet. Cherrylock rivets will qualify where you are now using a solid rivet, offering higher joint strength with greatly increased joint reliability under critical loading conditions—fatigue, shake and sonic vibration.

Now Cherrylock gives you a blind rivet that can be used in expensive forgings as well as for joining and attaching sheets.

For technical data on Cherrylock rivets, write Cherry Rivet Division, Townsend Company, Box 2157-C, Santa Ana, California.

*Patent No. 2931532

Cherry Rivet Division

Santa Ana, Calif.

Townsend Company

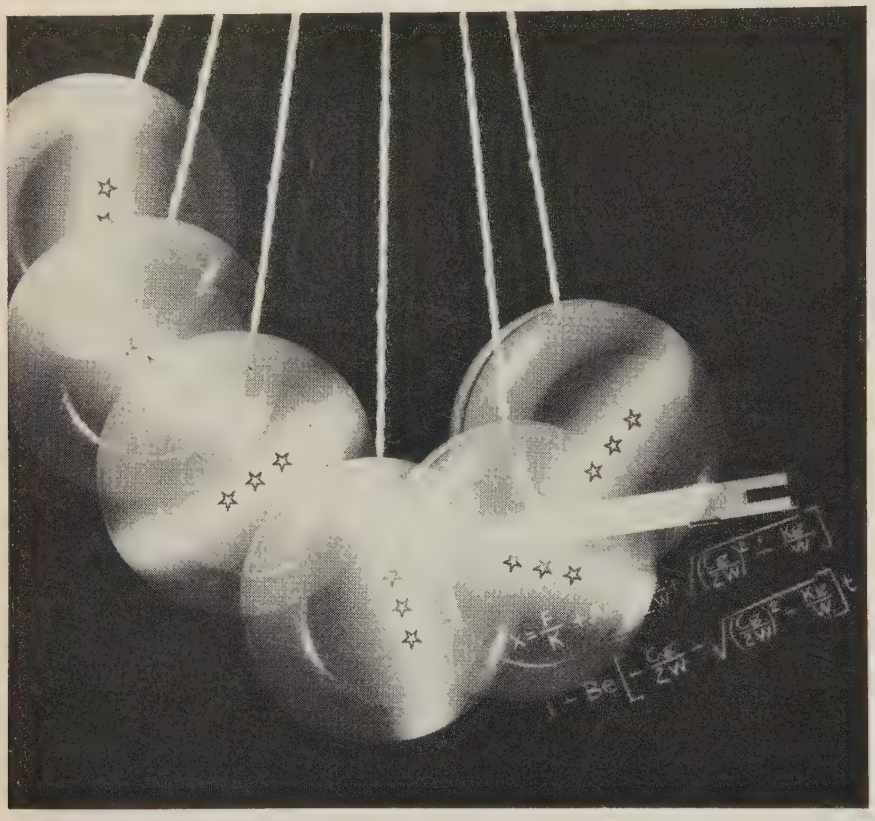
ESTABLISHED 1816 • BEAVER FALLS, PA. • A textron COMPANY

In Canada: Parmenter & Bulloch Manufacturing Company, Limited, Gananoque, Ontario

No. 118 on Reader Service Card

CAPABILITIES REPORT FROM BENDIX PIONEER-CENTRAL

INERTIA SENSING



INERTIA SENSING EXPERIENCE KEYED TO YOUR NEEDS!

From basic inertia sensing problems to the most sophisticated needs, Bendix—during the past 40 years—has been establishing constantly higher and higher standards in designing and producing inertia sensing devices. Turn and Slip Indicators, Indicating Accelerometers, Vertical and Rate Switching Gyros, Registering Accelerometers, Single and Double Integrating Accelerometers are all part of the evolution that has made Pioneer-Central a leader in this field. Here are experience and capabilities that can meet *your* inertia sensing needs.

Other areas of outstanding Pioneer-Central capabilities include—Cryogenics, Pressure Sensing Instrumentation, Life Sciences, Fuel Management, and Sonic Energy Cleaning.

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PIONEERING IS OUR BUSINESS

Pioneer-Central Division

THE Bendix CORPORATION

No. 119 on Reader Service Card

PULSE INSTRUMENTATION—A Short Form Catalog on a line of pulse instrumentation is offered by **Servo Corp. of America, Dept. S/A, 111 New South Rd., Hicksville, N.Y.** The 4-page folder reviews the functional modular approach to pulse instrumentation as an economical solution to special purpose equipment requirements.

No. 370 on Reader Service Card

FACILITY—An illustrated brochure describing engineering and production capabilities for electronic systems and precision products is available from **Nortonics, Dept. S/A, Research Park, Palos Verdes Estates, Calif.** Navigational systems, R & D, and manufacturing services are discussed.

No. 371 on Reader Service Card

HF SWITCHING — Bulletin 60-120, describing a switching system for audio, video, and HF switching, has been published by **James Cunningham, Son & Co., Inc., Dept. S/A, P.O. Box 516, Rochester 2, N. Y.** The bulletin discusses theory of operation and specifications.

No. 372 on Reader Service Card

INFRARED TRANSMITTERS—A listing of properties of infrared transmitting materials is presented in a brochure from **Sevro Corp. of America, Dept. S/A, 111 New South Rd., Hicksville, N. Y.** Specifications and transmission curves for each of 16 materials are included.

No. 373 on Reader Service Card

FILTERS—A new engineering bulletin, describing typical MIL-F-18327A filters, is now available from **Stancor Electronics, Inc., Dept. S/A, 3501 W. Addison St., Chicago 18, Ill.** The bulletin describes a wide variety of filters for telemetering band pass, high pass, low pass, line and other filter applications.

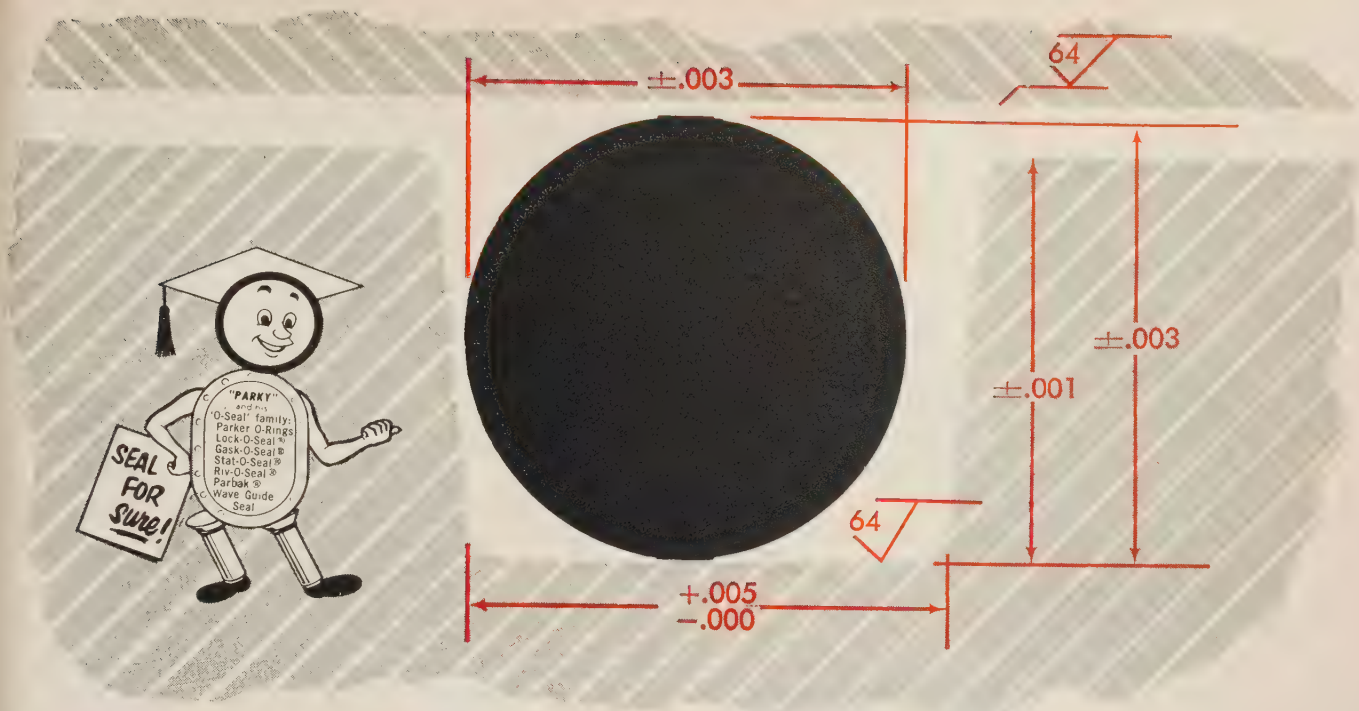
No. 374 on Reader Service Card

SILICON DIODES — Specifications of five high-current silicon diodes are now available from **Computer Diode Corp., Dept. S/A, 250 Garibaldi Ave., Lodi, N. J.** Maximum power dissipation is 600 mw at 25 deg C, operating temperatures range from −65 to +150 deg C.

No. 375 on Reader Service Card

FERRITE DEVICES — A new catalog listing a variety of ferrite devices has been announced by **Sylvania Electric Products, Inc., Dept. S/A, 1100 Main St., Buffalo 9, N.Y.** The catalog contains model numbers, frequencies, isolation and insertion loss, VSWR, power levels and dimensions of more than 50 ferrite units.

No. 376 on Reader Service Card



Cancel These Tolerances Specify GASK-O-SEALS®!

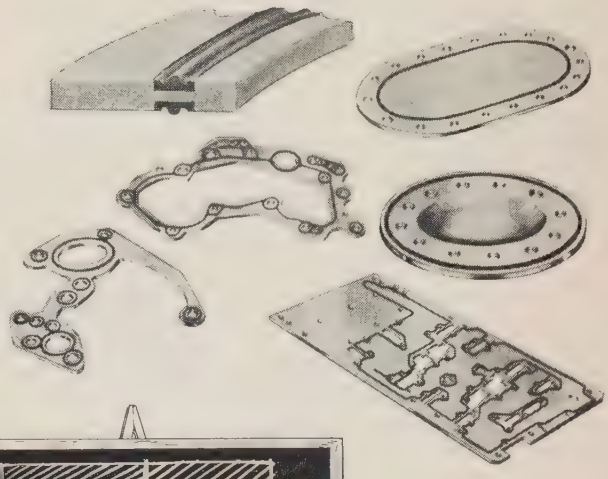
There are more than 5 vital dimensions in the standard O-ring-in-groove installation. Just one of these dimensions, if out of tolerance, can cause an imperfect seal and a resultant leak. Moreover, these tolerances can build up adversely **without always being detectable.** For instance, the total build up in a regular static o-ring gland design amounts to as much as 51% of cavity. It's only 3% in a Gask-O-Seal!

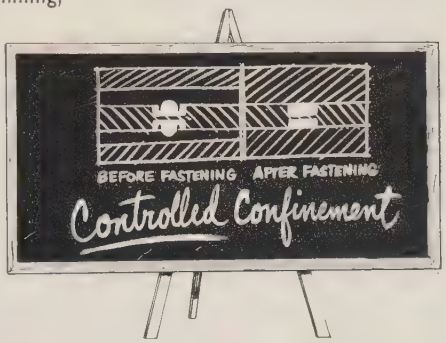
The problem of tolerances is eliminated when you use Gask-O-Seal . . . It's taken care of in its unique design and manufacture using the principle of **controlled confinement.** Gask-O-Seals eliminate 95% of inspection time. **Absolute reliability is built-in.**

In addition, Gask-O-Seals provide metal-to-metal contact, low fastening torques, visual inspectability after installation, no groove machining, and re-usability.

All of this means real no-leakage dependability . . . **the utmost in gasket reliability.**

Why not get **all** the facts about this versatile no-leakage seal. We'll be glad to send you complete information.





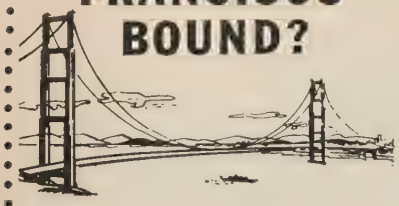
THE VERSATILITY OF GASK-O-SEALS IS SHOWN BY ABOVE SAMPLES — ONE OF THEM SEALS 3 DIFFERENT MEDIA AT 9 POINTS — ALL IN **ONE** GASKET!

Parker SEAL COMPANY

Culver City, California and Cleveland, Ohio

No. 120 on Reader Service Card

SAN FRANCISCO BOUND?



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Group facilities to 500.

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BELLEVUE HOTEL

at Taylor & Geary San Francisco

IN LOS ANGELES:
The Beverly Carlton, Beverly Hills—Hollywood Plaza, Hollywood—Skyways, International Airport

No. 121 on Reader Service Card

OSCILLOSCOPE GUIDE — A new replacement chart for oscilloscope cathode ray tubes has been made available by **Sylvania Electric Products Inc., Dept. S/A, 1100 Main St., Buffalo 9, N.Y.** The chart lists the oscilloscopes of 78 manufacturers by name and model number with cathode ray tubes.

No. 377 on Reader Service Card

TRANSISTORIZED CHOPPER—A miniature chopper that operates over a frequency range of 270 cps to 30 kc is the subject of a data sheet from **Solid State Electronics Co., Dept. S/A, 15321 Rayen St., Sepulveda, Calif.** The data sheet discusses applications; lists electrical and mechanical specifications.

No. 378 on Reader Service Card

INFRARED GLASS—A four-page brochure describing arsenic trisulfide glass for infrared applications is available from **Servo Corp. of America, Dept. S/A, 111 New So. Rd., Hicksville, N. Y.** The glass does not suffer elastic deformation under pressure, and has a coefficient of expansion approximating aluminum.

No. 379 on Reader Service Card

FACILITY—Capabilities in design, fabrication and assembly of electronic systems is discussed in a brochure from **National Geophysical Co., Inc., Dept. S/A, 2345 W. Mockingbird Lane, P. O. Box 35666, Dallas 35, Texas.** Areas of capability include research, development and production of equipment, assemblies and packaging.

No. 380 on Reader Service Card

WAVEGUIDE WINDOWS — Catalog WD-61, detailing complete electrical and mechanical data on nineteen solderable and flange waveguide pressure windows, is available from **Microwave Development Laboratories, Inc., Dept. S/A, Natick, Mass.** Window applications and manufacturing capabilities are discussed in the catalog.

No. 381 on Reader Service Card

ZENER DIODES — Subminiature glass silicon zener diodes are discussed in Bulletin SR-265 available from **International Rectifier, Dept. S/A, El Segundo, Calif.** Voltage ratings range from 3.0 to 33 volts; body length is 0.265 in. for the axial lead units.

No. 382 on Reader Service Card

SOUTHWEST "Monoball" SELF-ALIGNING BEARINGS

CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Steel Ball	For types operating under normal loads with minimum friction requirements.
4	"Dyflon"® Plastic Alloy Inserts. CRES Ball and Race. Chrome Alloy Steels.	For types operating under rotational, high radial loads and long cycle life where lubrication is impossible.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16" to 6" Dia. Our engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. Write for Engineering Manual No. 551. Address Dept. S/A 61.

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1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

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THIS SQUIRT LOOSENS-
FROZEN BOLTS
. . . BEARINGS

It's fast and accurate — shoots 15 feet — a drop or a squirt. It's labeled Kroil — so you can grab it quickly when a frozen bolt, screw or bearing starts to cost expensive time or threaten production.

That is when Kroil creeps into millionth inch spaces to soften rust, dissolve gum and supply lubrication to loosen the parts. It's fast and it's positive.

"Kano Kroil always opens up the tight fitting covers on fire extinguishers for us. We have found such covers we could not force off with a blow of a hammer. Several minutes' seepage of Kroil did the trick," so says a service organization for fire extinguishers.

If you are not one of the 19,000 industrial plants already using Kroil, send for a gallon on the proposition that it will loosen the most stubborn frozen part or you get your money back.

Kroilers are priced at $1.50 each. As an inducement to try Kroil we offer the combination of one Kroiler and one gallon of Kroil—(listed at $4.35) for $5.25 f.o.b. factory.

Ask for "Kroiler Deal" — order direct.

KANO LABORATORIES
1097 THOMPSON LANE, NASHVILLE 11, TENN.

No. 123 on Reader Service Card

SEMICONDUCTORS—A brochure describing the manufacture of transistors, diodes, and other semiconductor devices is available from **Sylvania Electric Products, Inc., Dept. S/A, 730 Third Ave., New York 17, N.Y.** The 12-page, illustrated brochure explains the role of research and testing in assuring reliable components.

No. 383 on Reader Service Card

DATA SYSTEM—A 16-page brochure describing a digital data acquisition system is available from **Consolidated Systems Corp., Dept. S/A, 1500 So. Shamrock Ave., Monrovia, Calif.** The brochure presents a brief functional description of all of the system's major components and includes detailed system specifications.

No. 384 on Reader Service Card

FACILITY—An illustrated brochure containing information on three facilities engaged in fabrication of military products is available from **Fairchild Camera and Instrument Corp., Dept. S/A, 300 Robbins Lane, Syosset, N.Y.** Products, systems, and support activities are described and pictured in detail.

No. 385 on Reader Service Card

TANTALUM CAPACITORS—Data sheets describing Types STA polar and Types STAN non-polar high uf solid tantalum capacitors have been announced by **Fansteel Metallurgical Corp., Dept. S/A, No. Chicago, Ill.** The bulletins cover electrical ratings, dimensional diagrams and performance curves.

No. 386 on Reader Service Card

ELECTRON TUBE—Uses of the Type 6939 UHF twin power pentode in RF amplifier applications is the subject of a brochure from **Radio Corp. of America, Electron Tube Div., Dept. S/A, Harrison, N.J.** The brochure, Application Note AN-192, describes circuits illustrating the use of the tube.

No. 387 on Reader Service Card

FM-FM TELEMETRY—A four-page illustrated brochure describing a new module concept approach to designing transmission systems is offered by **General Electric Co., Dept. S/A, 3198 Chestnut St., Philadelphia 1, Pa.** Advantages of the module concept and two typical systems using modules are cited.

No. 388 on Reader Service Card

REFLECTOR ANTENNAS—A report entitled, "Reflector Antennas for Radio and Radar Astronomy" is available from **Philco Corp., Dept. S/A, 3875 Fabian Way, Palo Alto, Calif.** A survey of electromechanical data on reflector-type radio telescopes are presented.

No. 389 on Reader Service Card

OSCILLATORS—Design features and specifications of crystal controlled oscillators are the subject of a catalogue from **Monitor Products Co., Dept. S/A, 815 Fremont Ave., So. Pasadena, Calif.** Frequency ranges vary from 25 to 250 cps and 900 kc to 20 mc, oven wattages range from 8 to 30 watts.

No. 390 on Reader Service Card

FERRITE CIRCULATORS—Catalog CR-61, four pages, describing a series of x-band ferrite circulators, is offered by **Microwave Development Laboratories, Inc., Dept. S/A, 15 Strathmore Rd., Natick, Mass.** Included are specifications, dimensioned drawings, and a description of operation.

No. 391 on Reader Service Card

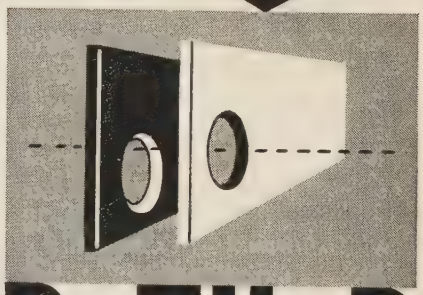
DIGITAL MODULES—A new product bulletin defining a wide variety of special-purpose digital sub-systems is offered by **Control Logic Inc., Dept. S/A, Natick, Mass.** The bulletin describes packaged code converters, arithmetic elements, control circuitry, and function generators.

No. 392 on Reader Service Card

MICROWAVE GENERATORS—A technical bulletin describing 17 stabilized microwave signal generators is available from **Strand Labs, Inc., Dept. S/A, 294 Centre St., Newton 58, Mass.** The generators are available in models covering the frequency ranges from L-Band to K-Band.

No. 393 on Reader Service Card

DON'T LET THIS



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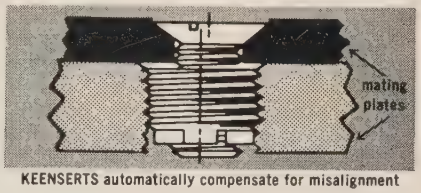
WHEN THE HOLES DON'T LINE UP USE FLOATING

KEENSERTS®!

You can save valuable dollars with these new **"floating"** Keenserts...they **automatically compensate** for misalignment (up to 0.040" for #10 and larger sizes). Available in 4-40 to 5/16-24 internal thread sizes.
Check how new "floating" Keenserts can reduce **your** manufacturing and assembly costs. Write for catalog "C" TODAY!

An Absolute MUST for the ELECTRONICS Industry!



KEENSERTS automatically compensate for misalignment

EASY INSTALLATION—All Keenserts...the new "floating"...those with regular or self-locking threads...the miniature and sub-miniatures...and the standard Keenserts*...all are easily and quickly installed using:

STANDARD TAPS, DRILLS and GAUGES ■ ONE-PIECE UNITS ■ WILL NOT PULL OUT ■ AVAILABLE from STOCK ■ Lock Bolts Entered ONLY A FEW TURNS per MIL-N-25027 ■ Have Positive Lock Against Rotation!

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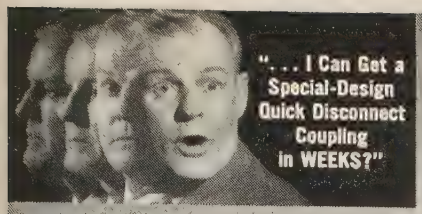

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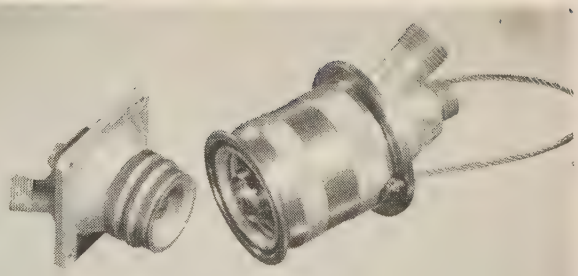

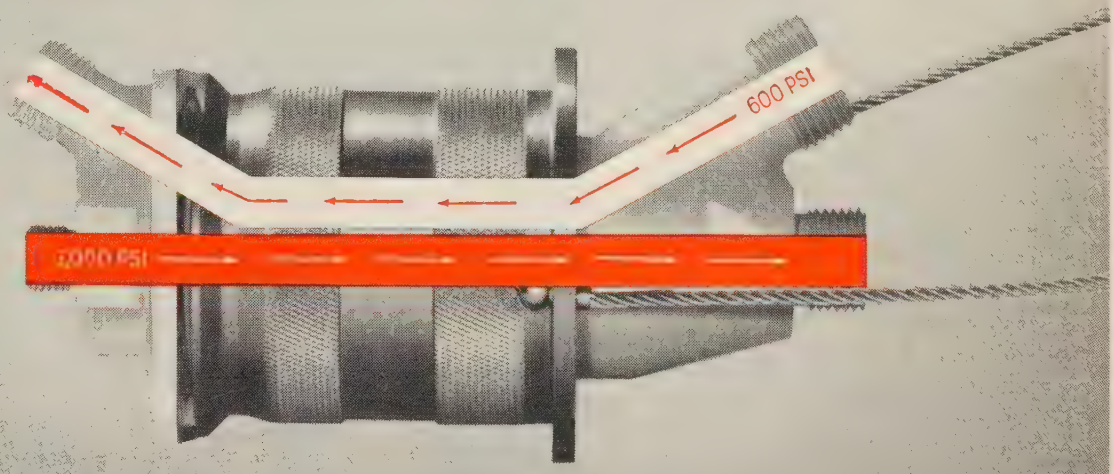

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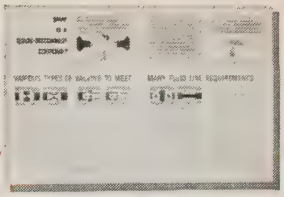

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32 Missile motor Copper blast cone; 88 lbs.
33 IRBM spacer ring; 78 lbs., Tungsten.
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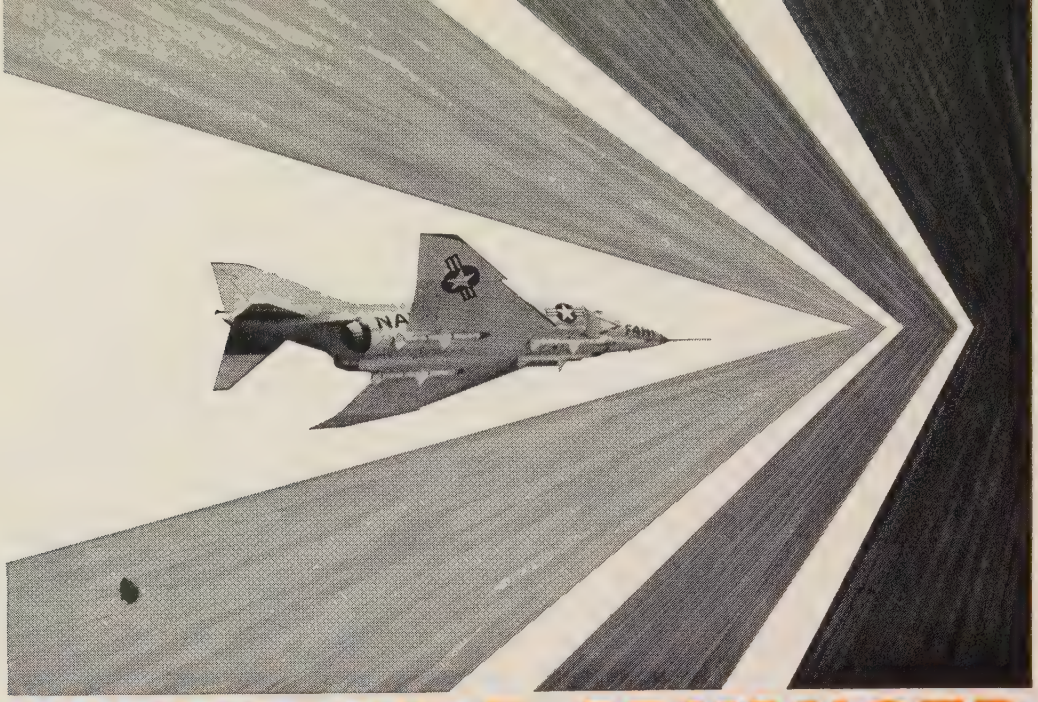

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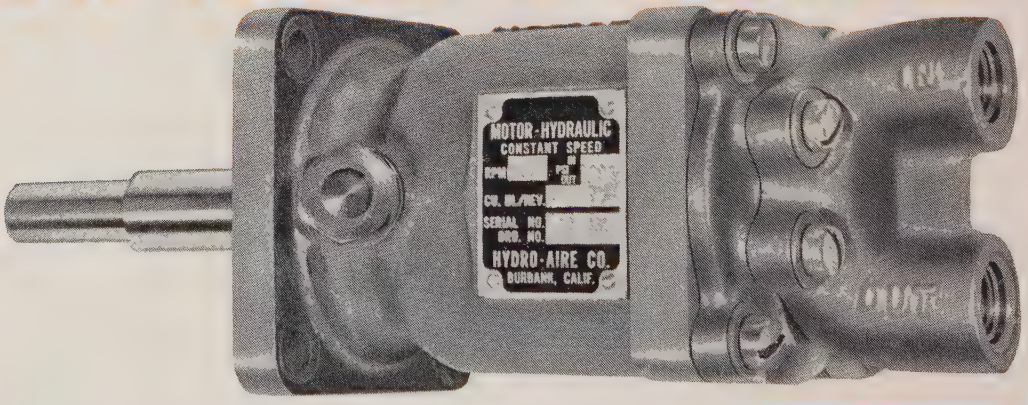

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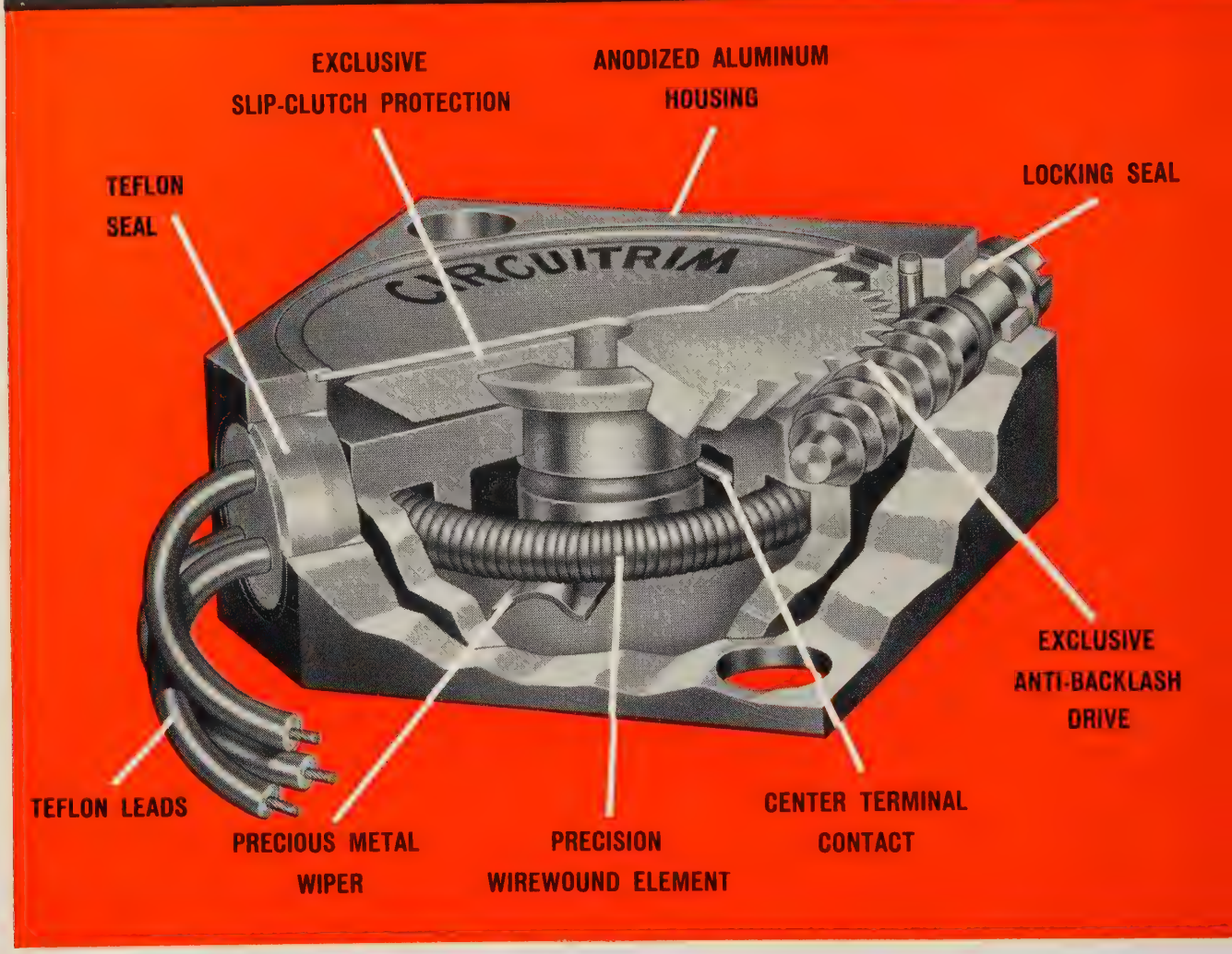

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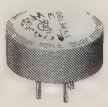

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dynamic instrumentation Σ

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Solution: A multiple-option approach with features dependent upon the specific job. Options include: Filter, limiter, bias, super power regulator, transient suppression and calibration insertion with the unique Endevco "charge" amplifier.

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Problem: Accurate measurement of structural impedance without significantly affecting the dynamic characteristics of the structure.

Solution: A very stiff and small combined force-accelerometer transducer incorporating the highly practical center-mounting configuration. The Endevco Model 2110 Impedance Head and Model 2953 Force Generator provide the ideal combination for accurate point measurement.

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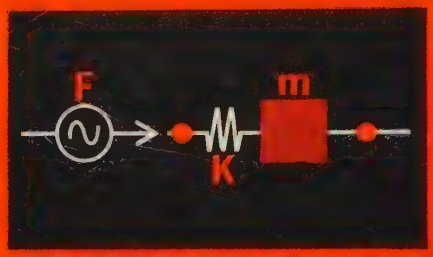
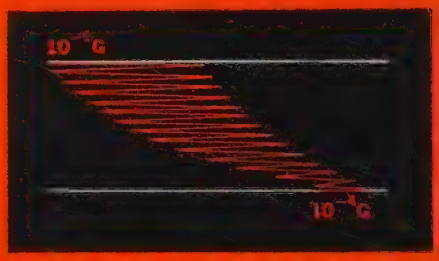
Problem: Broadband measurements of less than 0.0001 g with adequate signal-to-noise-ratio. The U.S. Navy "noise suppression" specification is one example [MIL-STD-740 (SHIPS)].

Solution: High output accelerometers, low noise battery operated preamplifiers, system protection against ground loop and stray field noise pickup. The Endevco 2870 and 2870M1 Systems provide these advantages.





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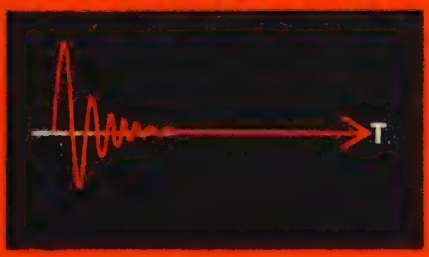

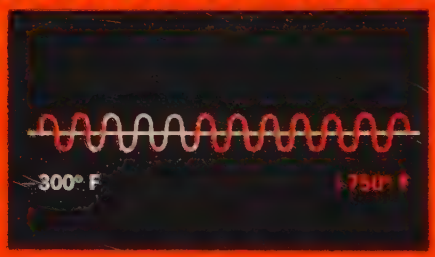

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Problem: Ruggedness, high resonance frequency and low frequency response to measure transients whose amplitude and pulse widths cover a wide dynamic range.

Solution: Model 2225 Accelerometer with 80 Kcps resonance frequency. Preamplifiers with flat low frequency response below 2 cps, wide dynamic range, RC time constant adjustment.

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Problem: Monitoring and/or recording dynamic outputs at semi-remote locations from piezoelectric transducers.

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- low power drain minimizes thermal problems and reduces power supply requirements.
- advanced manufacturing techniques including diffused planar structures, deposited leads, oxide protection, and hermetically sealed package—offer you the potential for improved circuit reliability.
- today's ultimate in microelectronics—with the highest function/size ratio for your digital circuits or equipments.
- provide reduced microelectronic cost through TI's standard silicon wafer design.
- meet military requirements:

Power Drain	2-4 mw @ 3 volts
Fan-Out (TI SN 510, 512, 514, 515)	4
Fan-Out (TI SN 511, 513)	20
Propagation Delay	75 to 450 nsec
Power Supply	3 to 6 volts
Temperature Range	−55° to +125°C

UNIT	TI SN 510	TI SN 511	TI SN 512	TI SN 513	TI SN 514	TI SN 515
FUNCTION	Flip Flop, Counter	Flip Flop with emitter follower output	NOR/NAND Gate (6 input)	NOR/NAND Gate (6 input) with emitter follower output	Two NOR/NAND Gates (3 inputs each)	Exclusive OR
	Clock pulse is internally capacitive-coupled					

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Temp., °F.	Viscosity, cs.	
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420	0.84	1.25
410	0.87	1.30
400	0.90	1.35
0	60	125
-10	80	170
-20	110	260
-30	160	380
-40	240	650
-50	400	1030
-60	700	1800
-65	934	2600
-80	2780	—

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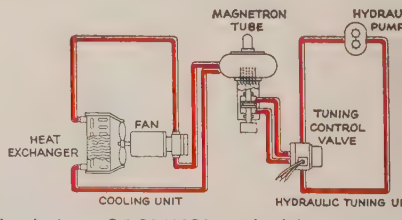
synthesize a liquid dielectric-coolant to meet stringent new military requirements—for critical heat control of compact electronic components that must *function flawlessly*—in supersonic aircraft, tactical missiles, tropical ground support complexes, and radar installations along the Arctic shores.

COOLANOL 35—a "chemically tailored" fluid combining excellent low-temperature viscosity—thermal stability—high dielectric strength—and good heat transferen in environments ranging from *a sizzli 420°F. to an icy -80°F.* (so cold lead pe cils won't write and ordinary rubb tires crack like eggshells)!



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Specific Gravity, 25/25°C.	0.889
Dielectric Strength, 25°C. (ASTM D877)	47KV
Thermal Conductivity, 25°C. (cal./sec. cm^2 °C. cm)	29.1×10^{-5}

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Tiny New 3/8″ (0.375″) Squaretrim® Potentiometer Dissipates One Full Watt In Still Air!

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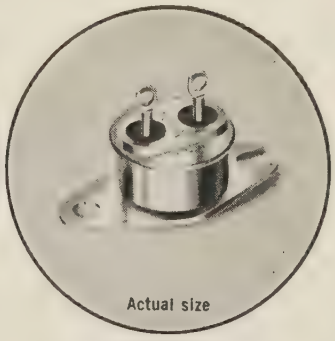
HIGH RELIABILITY FOR ELECTRONIC, RADAR AND RADIO EQUIPMENT; GROUND SUPPORT EQUIPMENT, AEROSPACE APPLICATIONS

NEW AT1-1 SUBMINIATURE PRECISION SWITCH

With a 0.440" height, 0.320" diam., KLIXON AT1-1 is a SPDT hermetically sealed snap-action switch. Weight: 1 gram. Shock resistant to 100 g's. Vibration resistant to 40 g's, 0-2000 cps. Current capacity: 3 amps, resistive 28 V-dc. Environmental free — complete seal assured even at high altitudes. Operates up to 275°F. Meets MIL-S-8484A, Class A.

Actual size



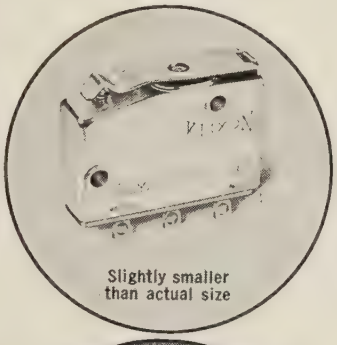
Actual size

HIGH RELIABILITY M1 PRECISION THERMOSTAT

Hermetically sealed SPST thermostat conforms with MIL-E-5272C and MIL-T-5574A. Snap-acting, disc type design for temperature control or warning on electronic and radar equipment, gyros, fuel pumps, servomotors, telemetering, de-icing and other equipment in critical avionic and aerospace applications. Vibration resistant right to operating temperature. Ambient temperature range —65° to +450°F. Minimum differential, 9°F. Ratings up to 7 amps, 30 V-ac/dc; 6 amps, 125 V-ac; 3 amps, 250 V-ac. Weight 3.7 gr basic unit.

KX-5 SERIES PRECISION SWITCHES

Hermetically sealed snap-acting limit switches. Seal uses metalized ceramic terminal inserts and metal diaphragm. Switching element, one-piece sine blade. Steel case withstands high impact and compression loads. High temperature resistance to 375°F. Vibration resistance to 25 g's, 0-2500 cps. Ratings to 10 amps, 115 V-ac or 30 V-dc resistive. 25,000 cycles minimum life. Ambient temperature range, —65° to +375°F. Weight 1 oz. Variety of actuators available.



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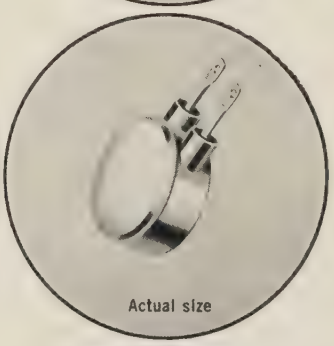


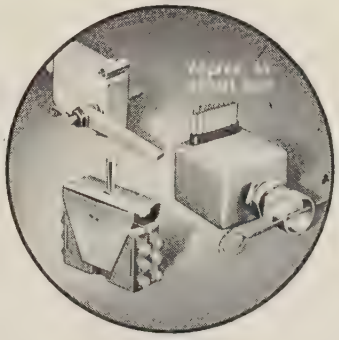
Actual size

NEW NARROW DIFFERENTIAL M2 PRECISION THERMOSTAT

Hermetically sealed SPST thermostat with positive snap action. Designed with a low silhouette, controls temperatures to narrow differentials. For use on electronic and military applications such as gyros, missiles, radar and other aerospace equipment. Ambient temperature range of —65° to +450°F, minimum differential of 2 to 5°F. Rating up to 2 amps, 30 V-ac and 125 V-ac for 250,000 cycles. Weight of basic thermostat: 3.76 grams.

PACKAGED PRECISION SWITCHES

KX and AT series hermetically sealed switches are used as basic units to build packages to meet customers' design needs. These "specials" include unique mounting configurations, connectors, leads, actuators, ganging of basic units, potting, etc. Environment free, metal-to-metal, glass-to-metal sealed. Qualified under MIL-S-6743, MIL-E-5272A, AN3234. The KX4 series has been assigned MS24456 (USAF).

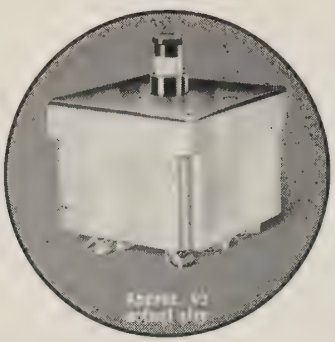


PACKAGED PRECISION THERMOSTATS

Custom designed thermostat packaging to meet special requirements based on KLIXON hermetically sealed M1 thermostats (see above). The special KLIXON Packaging Facility comprises a 3-part "hurry-up team" of designers, production specialists and testing personnel who will assign a part number at once and then meet exceptionally fast delivery requirements.

SMALL LOW AMPERAGE 7274 CIRCUIT BREAKER

Simple push-pull, trip-free design. Available as shown: DPST with solder auxiliary terminals and either screw or solder main terminals. Also, SPST with screw-type terminals. All models neck mounted. Neck bushing length 0.359" to accommodate 0.125" panels. Exceptionally small — depth of breaker behind panel, 1.420" max; height, 0.750"; width 0.562". Ratings ½ to 5 amps. Ultimate trip @ 77°F, 115-145%. 200% trip, 2-20 seconds. Vibration resistance 10 g's to 2000 cps. Shock resistance 35 g's. Weight only 0.9 oz. Also available in three-phase type.



THREE-PHASE D6760 SIMULTRIP* CIRCUIT BREAKER

Thermal type. Interrupts high ac short circuits . . . trips quickly . . . provides simultaneous tripping and trip-free action of all three phases should any one phase become overloaded. Phases can be different ratings. Ratings 5 to 60 amps. 120/208 V-ac, 60/400 cycle systems and 220/440 V-ac, 60/400 cycle systems. Weight 227 grams. Ac rupture capacity 2500 amps, 1ϕ, 120 V-ac, 400 cps. Ultimate trip @ 77°F, 105-138%. 200% trip, 10-70 seconds. D6760-1 is the MS21984 circuit breaker.

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KLIXON circuit breakers, precision switches, precision thermostats and thermal protectors are small in size and light in weight; they respond quickly and with accurate repeat performance; they have ample capacity to handle a wide range of electrical loads; their calibrations stand up in the face of severe environmental conditions.

Include a KLIXON field engineer in your early design discussions. For immediate information or assistance, call or write:

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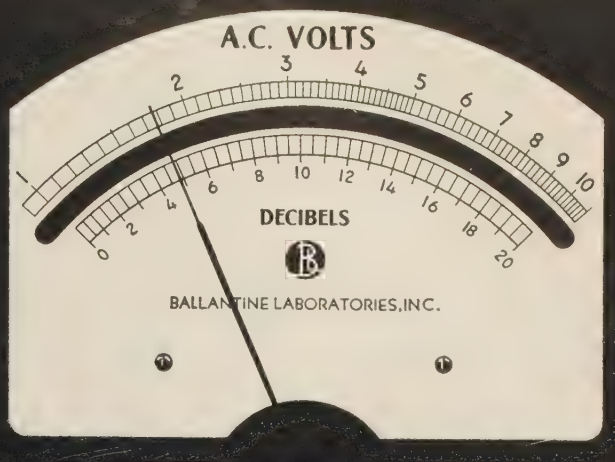
SAME HIGH ACCURACY OVER ENTIRE LOGARITHMIC VOLTAGE SCALE

BALLANTINE ELECTRONIC VOLTMETERS



AC/DC Calibrators, Capacitance Meter, AF Amplifiers, DC/AC Inverters, AC/DC Converters, and Accessories to extend Voltage Range from 10 Microvolts to 28,000 Volts. Laboratory Standards for Voltages to 1,000 MC.

Available in Cabinet and Rack Models. Prices F.O.B. Boonton, N. J., subject to change without notice.

ELECTRONIC VOLTMETERS

MODEL	FREQUENCY RANGE	VOLTAGE RANGE	INPUT IMPEDANCE	ACCURACY	PRICE
300	10 cps-150 kc	1 mV-100 V	0.5 MΩ shunted by 30 pF	2%	$220
300D	10 cps-250 kc	1 mV-1000 V	2 MΩ shunted by 15 to 25 pF	2%	$255
300E	30 cps-100 kc	300 μV-300 V	2 MΩ shunted by 20 to 30 pF	2%	$260
300G	10 cps-250 kc	1 mV-1000 V	2 MΩ shunted by 10 to 25 pF	1% 20 cps-20 kc, 1 mV-250 V; 2% elsewhere	$315
302C Battery Operated	2 cps-150 kc	100 μV-1000 V	2 MΩ shunted by 10 to 25 pF	3% 5 cps-100 kc; 5% elsewhere	$255
305A Peak Reading	5 cps-500 kc, sine waves. Pulses 0.5 μs up, and 5 pps up	1 mV-1000 V Peak or Peak-to-Peak	2 MΩ shunted by 5 to 15 pF	2% sine waves, 20 cps-200 kc; 4% elsewhere; 3% pulses above 3 μs and 100 pps; up to 5% elsewhere	$415
310A	10 cps-2 Mc; 5 cps-4 Mc as a null detector	100 μV-100 V (Down to 40 μV as null detector)	2 MΩ shunted by 9 to 19 pF	3% 15 cps-1 Mc; 5% elsewhere	$250
314 Wide Band	15 cps-6 Mc	1 mV-1000 V (100 μV-1 mV without probe)	11 MΩ shunted by 8 pF with probe, or 1 MΩ shunted by 25 pF without probe	3% 15 cps-3 Mc; 5% elsewhere	$300
316 Infrasonic	0.05 cps-30 kc; 0.01 cps with corrections supplied	0.02 V-200 V Peak-to-Peak	10 MΩ shunted by 17 to 40 pF	3%	$330
317 Wide Band	10 cps-11 Mc	300 μV-300 V	10 MΩ shunted by 7 pF with probe; 2 MΩ shunted by 11 to 24 pF without probe	2% 20 cps-2 Mc 4% 10 cps-6 Mc 6% 10 cps-11 Mc	$495 with probe
320 True RMS	5 cps-500 kc	100 μV-320 V	10 MΩ shunted by 8 to 18 pF	3% 15 cps-150 kc; 5% elsewhere	$445
350 True RMS	50 cps-20 kc	0.1 V-1199.9 V	2 MΩ shunted by 15 to 45 pF	¼% 0.1 V-300 V, 100 cps-10 kc; ½% outside these limits	$720

ELECTRONIC TEST EQUIPMENT

DECADE AMPLIFIER
Model 220C
Battery-operated amplifier, 10x or 100x; 10 cps-150 kc; 5 MΩ input; 2% accuracy. $115

CALIBRATOR. Precision dc and ac
Model 420
Provides precise output, rms, peak-to-peak, or dc, from 0-10 V; accuracy ¼% with cal. chart. $365

CAPACITANCE METER, Direct-reading
Model 520
Direct-reading of capacitance 0.01 pF to 12 μF; accuracy 2% above 0.1 pF. $335

INVERTER, Sensitive dc to ac
Model 700
Inverts dc as low as 10 μV and up to 100 V, to ac to be measured on any of VTVM's listed. $365

CONVERTER, Linear ac to dc
Model 710
Converts ac to dc linearly over each decade, 1 mV-1000 V; 30 cps-250 kc; accuracy ¼% 50 cps-10 kc, ½% 30 cps-50 kc, 1% above 50 kc. $450

LABORATORY STANDARDS

A-T VOLTMETER
Model 390
10 Mc to 1000 Mc; as laboratory standard for high voltage. NBS calibration not included in price. $2,250

H-F TRANSFER VOLTMETER
Model 393
25 cps to 30 Mc; a transfer device for accurate measurement of voltages or calibration of voltmeters; each probe covers 2 to 1 voltage range, 1 V to 50 V. $550 inc. one probe ($100 for each add. probe)

MICROPOTENTIOMETER
Model 440
0 to 900 Mc; as laboratory standard for 40 μV to 0.33 V. NBS calibration not included in price. Price includes one resistor-thermocouple combination. $250

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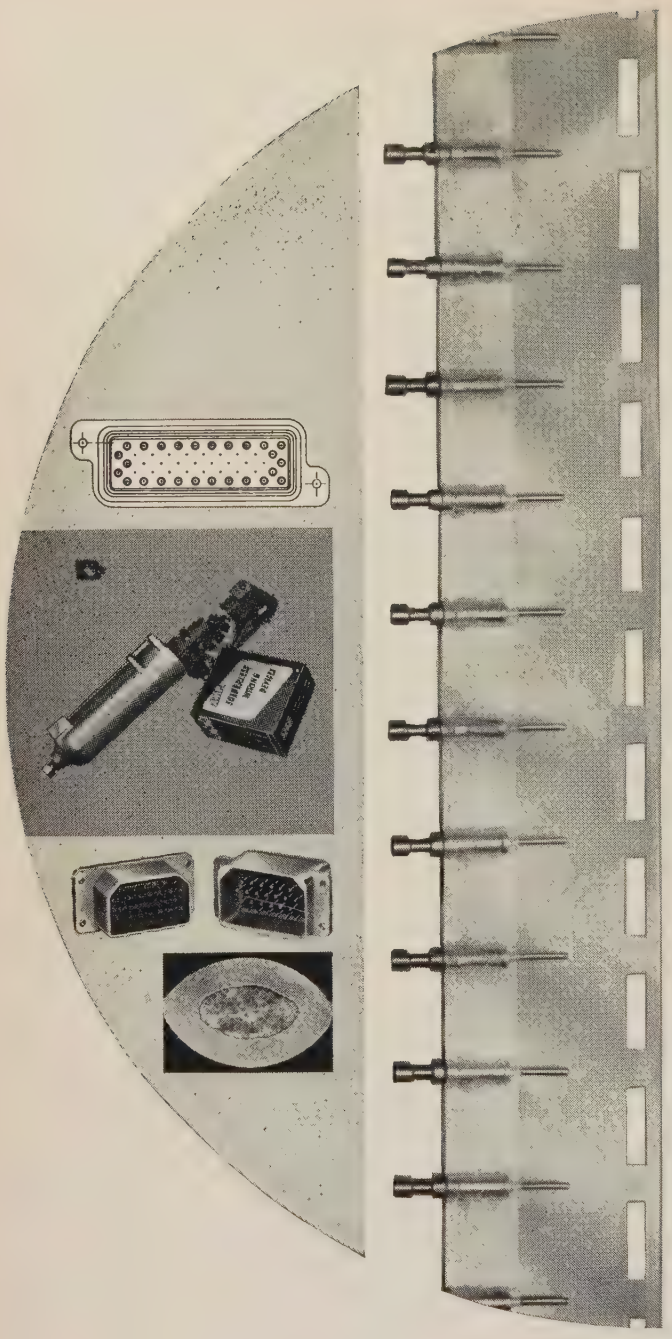

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When time counts, it usually adds up to money! Profit-nibbling time lost.

In the case of pin and socket connections, add the uncertain reliability of other methods of terminating connections and you've got good reason to consider AMPin-cert* Connectors with crimped, snap-in contacts.

AMPin-cert tape-fed, pin and socket contacts are precision crimped to leads on the AMP* Automachine at rates of more than 1,600 per hour. High production rates, maximum reliability and low cost of semi-skilled labor combine with dependable connector performance for the lowest installed cost in the industry.

Make a simple, preliminary test. Check these AMPin-cert Connector features against whatever you're presently using:

- Compression crimping of leads to contact for maximum reliability backed by more than 20 years of AMP experience in solderless termination techniques
- Choice of five types of contacts
- Snap-in design contacts with cantilever beam construction for easy insertion and dependable retention forces
- Choice of phenolic or diallylphthalate housings with or without cadmium plated aluminum shells in standard or environmentally sealed designs
- Wide variety of configurations and sizes and complete line of matching hardware and accessories.

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Design Guidelines for Air- and Spaceborne Electronics

Designing electronic equipment and systems for aerospace vehicles rarely is a straightforward problem of electronic performance. In fact, mechanical, thermal, and compatibility problems often loom larger than the strictly electronic ones. Even the simplest electronic design is complicated by the need to allow for the combined effects of rugged environments, for high reliability demands, for tight space and weight limits, and for the ever-present unknowns.

To the designer of aerospace vehicle electronics, this means that his electronic know-how by itself is not enough. He must also be well versed in mechanical design, heat transfer, shock and vibration protection, radiation shielding, sealing, corrosion-proofing, connection methods, production techniques, and reliability analysis, to mention just a few major areas.

The electronics engineer must also know the vehicle he is designing for—this is where his equipment must perform, not in the lab. Primary electric power, for instance, normally will come from the vehicle's electric system, which means the designer should be fully familiar with the supply voltage characteristics (performance under load, waveform, ripple, switching transients, etc.).

If vehicle-borne electronic equipment receives or emits electromagnetic energy, its designer should know the types of antennas and transmission lines that he may use as well as the limitations imposed by the vehicle on these elements. Since he cannot as a rule expect that his equipment will be installed all by itself, he must further be aware of the possible electromagnetic, thermal, and mechanical interactions between his equipment and both other equipment and the overall vehicle.

Lastly the electronic designer must know—certainly at the systems level—the mission of the vehicle in which his system will live and operate. It's just about axiomatic that you cannot intelligently design any piece of equipment if you do not know its end use and operating environment.

Designing the electronics of aerospace vehicles clearly involves a great many related areas that are not really electronic. When the problems in these areas become highly complex and assume major proportions, they should be turned over to specialists. But this does not relieve the electronic designer of the responsibility to know enough about these related technologies so that he can understand their problems and understand how the solutions of these problems affect his design.

It is for all these reasons that, of the ten areas covered by SPACE/AERONAUTICS', *"Design Guidelines for Air- and Spaceborne Electronics" only two involve electronics in the strict sense ("Digital Circuit Design" and "Component Applications"). The other eight areas all involve problems that are closely related to electronics—so closely related, in fact, that their solution is essential for successful electronic design.*

James Holahan
Bernard Kovit
Electronics Editors

Environments of Electronics

NATURAL

	CHARACTERISTICS	EFFECTS ON MISSILE & SPACECRAFT ELECTRONICS*	DESIGN COUNTERMEASURES
Ambient temperature	Sources: thermal radiation from direct sunlight, earthshine (albedo), direct earth radiation; heat generated within the vehicle. Contributions of albedo & direct radiation fall off with distance from earth (e.g., energy at 4000 mi is 20% that at 200 mi). Major source is solar; solar constant is 2.0 cal/cm²-min at earth's mean distance from sun. Heating & cooling by radiation only. True space heat sink is 4° K.	Losses of mechanical integrity: leakage of sealed units, particularly at union of dissimilar metals; expansion; metal creep, fatigue, sublimation. Knowledge lacking on thermal surface properties at very high vacuum & on temperature distribution due to radiation flux on small, complex assemblies with many joints in thermal paths.	Overall problem not severe. You can generally control temperature with absorptive and reflective surfaces with heat-control servo circuits. Isolate inter equipment for 0°-60° C (depending on requirements). Use radiation & conduct heat transfer. Convoluted chassis walls give better heat absorption than flat or curved ones. Controlled heaters or thermoelectric coolers & mechanically operated, thermal-sensor-controlled radiation louvers give active heat-balan regulation. Spinning the vehicle elimina temperature gradients around surface.
High Vacuum	At 10-120 mi over earth, pressures represent partial space equivalent. Beyond 120 mi, pressures from 1.5×10^{-6} mm Hg to est. 1.5×10^{-12} for solar system space. Intergalactic spatial pressures est. at 10^{-15}—10^{-20} mm Hg.	Arc-over & corona discharge; boiling of liquids at lower temperatures; absence of air damping in vibration; explosive decompression in hermetically sealed units; sublimation & evaporation of inorganic materials; etc. In sealed units that are not vacuum-tight, more volatile materials may evaporate from hotter parts & condense on colder ones as thin films. Outgassing can have corrosive, plating, & chemical effects. Certain nylons, polyesters, & epoxies lose up to 10% of weight per year in vacuum at 100° F; polyurethane, at 150° F; neoprene & alkyd, at 200° F; butyl rubber & phenolics, at 250° F.	Use materials with low sublimation rate Allow enough thickness for sublimation & evaporation over expected operating life. Select adequate insulating materia provide insulation to prevent arc-over or corona discharge.
Solar Radiation	Electromagnetic (photon) & corpuscular (particle) emission over wide range of energies from UV through IR (100-100,000 A); about 40% in 3800-7000 A (corresponding black-body temperature: around 6000° K), 22% in 7000-10,000 A, 33% in 10,000-20,000 A. All radiation above 40,000 A absorbed by atmosphere. Particulate emission produces "solar wind" or plasma. Photon intensity (gamma rays) reaching atmosphere is about 1.4×10^{6} erg-cm^{-2}-sec^{-1}. Solar flares can alter intensity by as much as 2-5 orders of magnitude.	Most significant apears to be UV band below 2400 A & its effects on organic materials. Degradation usually depends on exposure time; rubbers & plastics are particularly susceptible. Polyesters, phenolics, glass laminates, epoxies, etc., prone to sublimation. Boost-glide & low-orbit vehicles, operating at 100,000-300,000 ft, exposed to 2000-3000-A radiation as well as greater intensity of UV above 300 A and X-rays at higher levels of this range. Generally, though, UV rays pose little threat for electronics—they cannot penetrate even thin sections of materials. Best estimates show equipment operating in space must stand up under energy that produces 7.4 btu/sq ft/min at one astronomic unit from sun. (At other distances, amount is inversely proportional to square of distance.)	Against flare particles of high energy & intensity occurring during major solar disturbances, normal protective measur don't work. Extra shielding would be or countermeasure, though it might often b futile. For normal corona conditions, ordinary metal structures shield most susceptible electronics (e.g., 0.040-in.-thick plate of Al absorbs over 90% of incident radiation). Use thin glass over-layers on solar cells to keep them from deteriorating. For vehicles that may undergo long exposure periods, use ext shielding around semiconductor device
Ionized & Dissociated Gases	Form at altitudes above 55-57 mi as solar radiation changes chemical activity of normal gases. In altered or excited state, dissociated gases may have highly accelerated oxidation rates—e.g., oxygen & nitrogen become monatomic above 62 miles. Hypersonic flight can induce thermal extremes within the vehicle boundary gas that will produce dissociation & ionization depending on equilibrium conditions of temperature & pressure.	Most serious effect of ionized gases is disruption of communications by reflecting radio waves. Dissociated gases can do actual damage to electronics—e.g., monatomic oxygen reacts very readily & rapidly (forming oxides) with materials like Fe, Fe oxides & alloys, Cu, Ag & many organic materials.	Protect susceptible components with coatings, particularly in vehicles traver ing the ionosphere at shallow slant ang Make sure electronics-compartment sea are gas-tight & all air has been remove from compartment & individual package
Cosmic Radiation	Consists of non-electromagnetic atomic particles. Over 90% are protons, about 7% are alpha particles, less than 1% are electrons, remainder are nuclei of heavier elements. Secondary particles of cosmic radiation include all particles known to physics as well as high-energy gamma rays. Energies average around 3.6×10^{9} ev and can go as high as 10^{17} ev.	Only negligible material damage expected. Remote possibility of direct hit by particle of very high specific ionization—could be very damaging to electronic equipment, especially if small, vital component were hit.	Shielding requirements vary with flight profiles & exposure time. Design criteri are being prepared.
Van Allen Radiation	Made up of charged particles (almost all protons & electrons) trapped by earth's magnetic field. Particles concentrated in 2 concentric "belts" of relatively high intensity. Inner belt: about 2200 mi above the geomagnetic equator; made up primarily of protons of over 40 mev; also has some electrons of 20-600 kev. Outer belt: about 18,500-20,000 mi up; particles are primarily electrons from 20 kev to 2.5 mev; some protons of over 60 mev. Latest findings show small pockets of higher intensity may move within the 2 zones.	Significant equipment damage only after prolonged exposure. This radiation can be damaging to devices that depend on crystal or molecular orientation—semiconductors, magnets, etc., particularly vulnerable. Solar cells can lose 50% of output in several months. Organic materials subject to molecular distortion.	For prolonged, unavoidable exposure, shielding must be used. Requirements vary with flight profile & exposure time. Shield solar cells with thin glass coatin
Nuclear Radiation	Sources: neutrons, alpha, beta & gamma rays from primary or secondary power plant; nuclear weapon; natural space radiation. Only neutrons & gamma rays penetrate shielding. Neutron energies from 40-50 kev to 17-20 mev (about 35% at 0.8 mev). Gamma-ray energies from about 300 kev to at least 8.0 mev (average about 1.5 mev).	Permanent damage caused by fast neutrons colliding with & displacing atoms or by Compton scattering. Transient effects caused by secondaries of neutron & gamma primaries infusing circuits & ionization. Resistors & Semiconductor Diodes: Resistance decreases with release of new current carriers or may increase with production of new scattering centers. Capacitors: ionization-caused leakage through & around dielectric. Transistors: Like diode, affected mainly by changes in conductivities of various regions.	Shielding & component selection, are o countermeasures. Generally avoid use semiconductors. Recommended compo-nents: tubes (ceramic & subminiature types), capacitors (ceramic, glass, mic resistors (wirewound), insulators (cera or other organic), connectors (glass-bonded mica).

*On **aircraft electronics,** natural enrivonments have either no effects at all or only insignificant ones. Exposure times to solar radiation, for instance, are far below the limits at which damage occurs.

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INDUCED

CHARACTERISTICS	EFFECTS: AIRCRAFT ELECTRONICS	EFFECTS: MISSILE & SPACECRAFT ELECTRONICS*	DESIGN COUNTERMEASURES	
Relatively sustained periodic or random motion excited by force, motion, or both. Major sources are jet & rocket exhaust, aerodynamic flutter, rotational imbalance, servo-control instabilities, propulsion system pulsations, air pressure fluctuations. Filtering by intervening structures generally lets only random vibration reach internal equipment. Structural effects involve 5-2000 cps. Electronics are most susceptible to frequencies out to 800 cps.	Excessive or prolonged vibration can cause loosening of components & connections, relative motion between parts & equipment, gyro drift, coupling of body-bending modes with control system sensors, mechanical fatigue failure.	Relatively unimportant, except for launch environments. No frictional or combustion vibration problems except in special classes of vehicles with boost-glide or low-orbit flight profile or with restart.	Try to use mechanical items (valves, hydraulic controls, APUs, pumps, etc.) whose resonances lie outside the vibration frequency spectra. Use high-density electronic modules, particularly the solid or potted types. (Molecular electronics should prove a boon.) Choose electronic equipment with high mass-area and high stiffness-mass ratios. Fill all free space in packages with foam or denser materials. Make all suspension mounts isoelastic. Locate gyros & accelerometers at nodes.	Mechanical Vibration
Vibrations excited by oscillatory sound pressures (beyond 130 db). Fluctuating sound pressure fields generated by jet and rocket engine exhausts. Boundary-layer turbulence is second in importance. Average sound levels: most jets, 140 db & as high as 150 db within several feet of noise source or in 45° noise cone; payload & nose-cone electronics of ballistic missiles & boosters, 155 db; booster compartment & pods at sides of boosters, 165 db (maximum reported for conventional launch: 186 db).	Jet exhaust sound pressures excite structural vibrations that are transmitted to system units attached to structure. Random vibration is particular problem. Most sensitive are microphonic components wth high frequency resonances: electron tubes, waveguides, klystrons, magnetrons, piezoelectric devices, relays attached to thin plates. Also susceptible are units that contain diaphragmatic elements like pressure transducers, valves, switches, relays, flat spiral-antenna elements.	Important only in launch-boost phase, where fluctuating sound pressures on structure are growing problem. Acoustic stresses, which would occur only in very exceptional cases in space, never approach intensity of those in boost phase.	Generally same rules of conservative design as for mechanical vibration. Mount modules or packages containing solid-state elements on small areas of properly constrained or damped circuit boards or matrixes. Select units & components carefully, particularly for re-entry, recovery, landing & other complex missions. For these, general rule that equipment designed to withstand launch & boost phases will work in space may have to be revised.	Acoustic Vibration
Major sources of sustained acceleration are booster propulsion & aerodynamic drag during re-entry. Exposure time in boost from 5 to 200 sec. Manned vehicles limited to short periods of no more than 8-12 g. Predicted sustained launch and boost accelerations through mid-'70s: large vehicles, 8 g; medium, 20 g; small, 50-100 g. Re-entry accelerations: vertical injection, 300 g; vertical injection at suborbital speeds, 100-110 g max.; 1.5-deg entry angle, 8.5 g.	Components are stressed in direct proportion to magnitude of acceleration in direction of force. Effects include bottoming of shock & vibration mounts, erratic operation of spring-mounted devices, drift in gyros & stable platforms, sensitivity changes in accelerometers.	Important in launch & boost phases mainly. For re-entry, recovery, landing, & other maneuvers, poses distinct threat to suspended units and elements.	Same measures as for vibration. Generally try to substitute solid devices & components for those in which dynamic balance or orientation is critical.	Acceleration
Self-generated heat, frictional heating, internal gradients are main induced thermal stresses affecting electronics. In aerodynamic vehicles, skin friction heat-up may reach about 500°-700° F. Re-entry vehicles may generate up to 5500° F. Presently planned spaceflight profiles limit skin temperatures to 1200°-2400° F in boost phase, 2100°-3100° F in sub orbital re-entry, 36° F/sec rate of change. Internal heat from 25,000° F nuclear engines will pose problem.	Transistorized equipment specially susceptible to thermal stress. Heat dissipated by various elements could knock out transistor circuits, induce resistance changes, cause frequency shifts & electrical noise, break down insulation, etc. Effects are particularly critical if high temperature is combined with vibration, shock, acceleration. Problem is minimal in subsonic flight regimes. Supersonic & hypersonic flight pose greater problem—kinetic heat-up of vehicle & immediate environment demands cryogenic & other complicated methods of heat transfer.	No available electronic components can withstand re-entry temperatures. Best components limited to around 800° F max. Thermal shock can damage components & materials at considerably lower temperatures. Degree of dissociation, extent of chemical change, heat transfer coefficients, and radiation effects are big unknowns.	Supersonic aircraft electronics demand forced conduction or convection heat transfer. Radiation and conduction heat sinks are only methods in space. Ablative or reflective nose cones must be used to shield all re-entry electronics. (See also counter measures for ambient temperature.)	Temperature
Difference between shock & vibration is one of degree. Shock can occur as abrupt change in magnitude or direction of velocity or in previously steadily aplied force. Levels depend on the type of vehicle, flight profile and conditions, methods of packaging. Mach 1+ aircraft flight can produce 10-15 g; missile flight, 25-50 g; booster separation, up to 200 g for 1-2 millisec.	Most important effect is excitement of natural oscillatory or vibration modes that can lead to intermittent faults in components. Shock can cause catastrophic failures: shattered tube envelopes, fractured mountings of high-density packages, buckling of column structure. Faults also stem from shock-dislocated tube elements, stepping of relays, momentary loss of continuity in circuits. Combined with high temperatures, effects are greatly aggravated.	Relatively unimportant except for severe stresses during launch and boost phases.	Same as for mechanical & acoustic vibration.	Shock

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Simplified Reliability Mathematics and Statistics

THE BINOMIAL DISTRIBUTION

WE CAN SAY that $b(x,n,p)$ is the probability that n Bernoulli trials[1] with a probability p of success and q, or $1-p$, failure will result in x successes and $n-x$ failures (for $0 \leq x \leq n$). The common expression for the binomial distribution then is:

$$(1) \qquad b(x, n, p) = \binom{n}{t} p^x q^{n-x}.$$

By using the two identities:

$$(2) \qquad q = 1 - p, \binom{n}{x} = \frac{n!}{x!(n-x)!},$$

we can rewrite *Equation 1* as:

$$(3) \qquad p(x) = \left[\frac{n!}{x!(n-x)!}\right] p^x (1-p)^{n-x}.$$

This equation represents the xth term of the binomial expansion of $(p+q)^n$, which describes the probability distribution of repeated trials of the same event. We can also say that *Equation 3* represents a specific pro ability of exactly x successes in a sample n when t probability of success is p. (These exact probabilities a given in detail in many binomial tables.[2])

Often the cumulative probabilities must be know as well as the exact probabilities. Conventional metho of summing can be used to find them, but they are cur bersome. The answer can be defined more simply fro the basic nature of the binomial expansion series.

Suppose the mean time between failures (MTBF for a piece of equipment is known, the equipment to be used on four 50-hour missions without mai tenance. The problem is to determine the chances success on the four missions.

If you are familiar with the exponential failure la you will recognize that, as the MBTF is known, t probability of success is easily found from:

$$(4) \qquad P_s = e^{-t/m}$$

The known MTBF can be substituted in this equati along with the time of mission (t=50), and you c

* El-Tek Corp., 13040 Cerise Ave., Hawthorne, Calif.

(1) A sequence of independent trials in which the probability of "success" is the same for each trial.

(2) Hald, "Statistical Tables and Formulas"; Wiley. Orlen, Colt "Tables for Statisticians"; College Outline Series. Mood, "Introduct to the Theory of Statistics"; McGraw-Hill.

Table I: Pascal's Triangle

Number in Sample	Coefficients in Expansion of $(p+q)^n$
n	1 1
1	1 2 1
2	1 3 3 1
3	1 4 6 4 1
4	1 5 10 10 5 1
5	1 6 15 20 15 6 1
6	1 7 21 35 35 21 7 1
7	1 8 28 56 70 56 28 8 1
8	1 9 36 84 126 126 84 36 9 1
9	1 10 45 120 210 252 210 120 45 10 1

*Constructed by making each term from the second line on, equal the sum of the terms in the two adjacent columns and the next-higher line.

Table II: Exponential Failure Law ($P_s = e^{-t/m}$)

$\frac{t}{m}$	P_s	$\frac{t}{m}$	P_s	$\frac{t}{m}$	P_s
0.01	0.99	0.65	0.522	2.3	0.10
0.02	0.98	0.70	0.496	2.4	0.09
0.03	0.97	0.75	0.472	2.5	0.08
0.05	0.951	0.80	0.449	2.6	0.07
0.08	0.923	0.85	0.427	2.7	0.06
0.10	0.904	0.90	0.406	2.8	0.06
0.12	0.887	1.00	0.367	2.9	0.05
0.15	0.860	1.1	0.332	3.0	0.04
0.18	0.835	1.2	0.301	3.1	0.04
0.20	0.818	1.3	0.272	3.2	0.04
0.22	0.802	1.4	0.246	3.3	0.03
0.25	0.778	1.5	0.223	3.4	0.03
0.30	0.740	1.6	0.201	3.5	0.03
0.35	0.704	1.7	0.182	3.6	0.02
0.40	0.670	1.8	0.165	3.7	0.02
0.45	0.637	1.9	0.149	3.8	0.02
0.50	0.606	2.0	0.135	3.9	0.02
0.55	0.576	2.1	0.122	4.0	0.01
0.60	0.548	2.2	0.110	5.0	0.00

by Clifford M. Ryerson, *Vice President, El-Tek Corp.**

solve for P_s:

(5) $$P_s = 80\% = p = 0.8.$$

Using $q = 1 - p = 0.2$ and $n = 4$ (missions), you can expand the binomial:

(6) $$(p + q)^n = (p + q)^4 = p^4 + 4p^3q + 6p^2q^2 + 4pq^3 + q^4.$$

The terms of this expansion stand for the probabilities of all four successes, three successes, two successes, and so on. By substituting the values for our hypothetical mission, you get the exact probabilities of, respectively, four, three, and two successes, a single success, and zero success in four missions:

(7)
$$P_4 = p^4 = 0.8^4 = 41\%,$$
$$P_3 = 4p^3q = 4 \times 0.8^3 \times 0.2 = 41\%,$$
$$P_2 = 6p^2q^2 = 6 \times 0.8^2 \times 0.2^2 = 15\%,$$
$$P_1 = 4pq^3 = 4 \times 0.8 \times 0.2^3 = 2.5\%,$$
$$P_0 = q^4 = 0.2^4 = 0.16\%.$$

The cumulative probabilities now are a matter of simple additions. Those for three or more and two or more successes, for instance, are:

(8) $$P_3 + P_4 = 82\%, \quad P_2 + P_3 + P_4 = 97\%.$$

If you don't want to bother with expanding binomials, you can instead use Pascal's triangle (*Table I*). This simple table makes it easy to find the numerical coefficients for a binomial-series expansion.

THE EXPONENTIAL SERIES

RELIABILITY calculations commonly involve the exponential failure law and Poisson's reliability distribution. Both are related to the binomial distribution. The Poisson distribution actually is a good approximation of the binomial if the number of trials is large and the chance of failure small.

The mathematical notation for an infinite series,

$$\sum_{i=0}^{\infty} \frac{1}{i!}$$

is not as familiar to most engineers as the constant 2.71828 for the Napierian base e. Yet this value is found by working out and summing the terms of the infinite-series equation:

(9) $$e = 1/0! + 1/1! + 1/2! + 1/3! + \cdots \infty.$$

Now if we raise the constant e to any power a, the

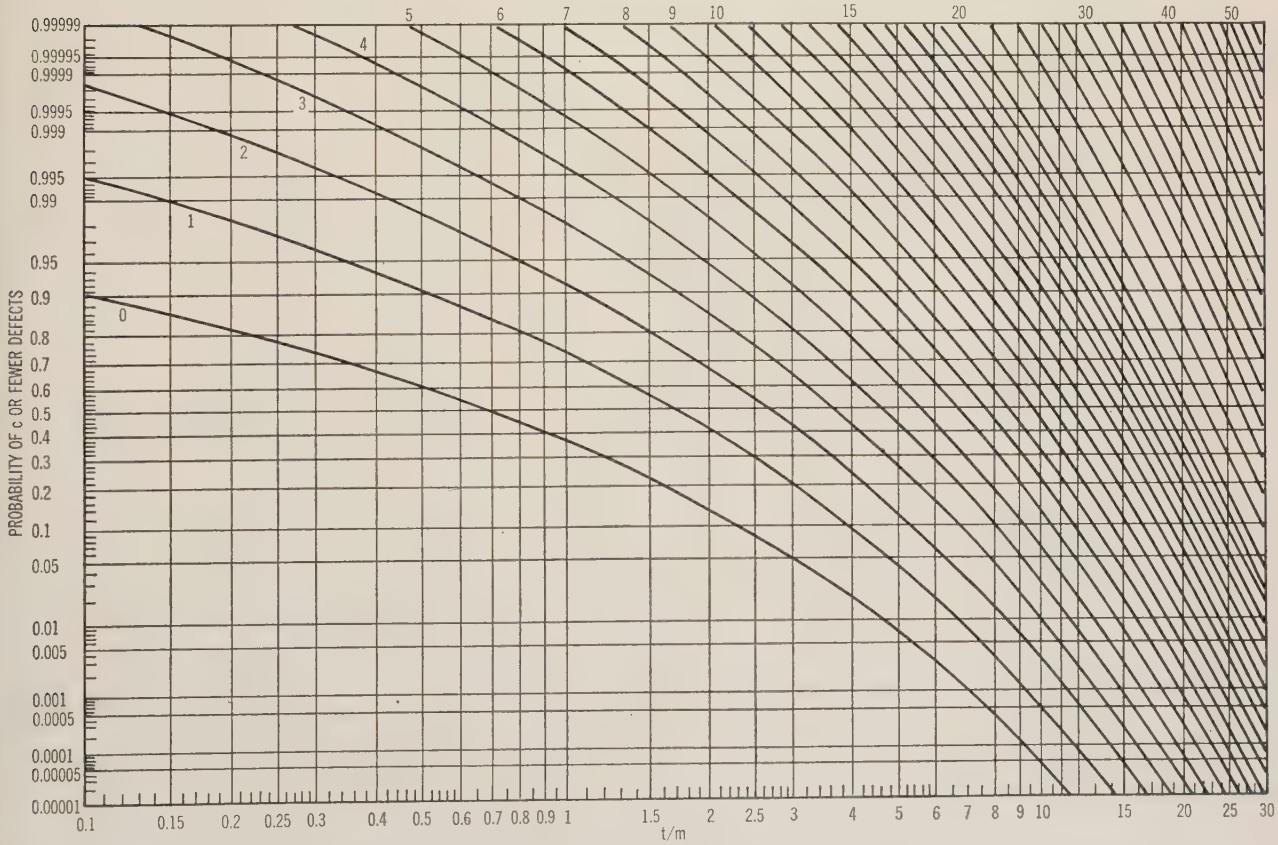

FIGURE 1: Cumulative probabilities for f—1 or less are shown by this graph (modified from one developed in 1926 by F. Thorndike) for determining the probability that c or fewer defects will occur in a sample of n pieces selected from an infinite universe whose fraction defective is p. On the abscissa, t/m equals pn.

result can be expressed in the form of an infinite series similar to the series for e itself:

(10) $e^a = a^0/0! + a^1/1! + a^2/2! + a^3/3! + \cdots \infty.$

As a^0, 0!, and 1! each equals unity, *Equation 10* becomes simply:

(11) $e^a = 1 + a + a^2/2! + a^3/3! + a^4/4! + \cdots \infty.$

In any distribution to be used as a probability distribution, the sum of the terms must equal unity. *Equation 11* therefore must be multiplied through by e^{-a}:

(12) $$P_t = e^{-a}e^a = 1.$$

This equation can also be written:

(13) $P_t = e^{-a}(1 + a + a^2/2! + a^3/3! + \cdots \infty).$

The result of the multiplication is:

(14) $P_t = e^{-a} + e^{-a}a + e^{-a}a^2/2! + e^{-a}a^3/3! + \cdots \infty.$

Each of these terms is identical with the familiar Poisson expression $e^{-a}a^c/c!$

If you substitute the normalized time (t/m) for a in *Equation 14*, you get:

(15) $$P_t = e^{-t/m} + e^{-t/m}\frac{t}{m} + \frac{e^{-t/m}(t/m)^2}{2!} + \frac{e^{-t/m}(t/m)^3}{3!} + \cdots \infty.$$

You have now derived *both* the exponential failure law (the first term of the Poisson series) and the Poisson reliability distribution. The terms of *Equation 15* successively give the exact probabilities of zero, one, two, three and all other numbers of failures for various values of t/m, where t is the time of operation and m is the MTBF.

THE EXPONENTIAL FAILURE LAW

THE FIRST TERM of the infinite Poisson series we have just derived gives the exact probability of zero failure, which is the same as success. The probability of success therefore can be expressed simply as:

(16) $$P_s = e^{-t/m} = e^{-\lambda t},$$

where λ is the failure rate and equals $1/m$.

To show how the exponential failure law is applied, let's take the case of some equipment whose MTBF is 200 hours and for which we want to know the chances of no failure on a 50-hour mission. Substitution in *Equation 16* gives the answer:

(17) $$P_s = e^{-50/200} = 77.8\%.$$

Table III: Percentage Points of the Chi-Squared Distribution

Degrees of Freedom (f)	Probability of Greater Value					
	0.95	0.90	0.80	0.20	0.10	0.05
1	0.00393	0.0158	0.0642	1.64	2.71	3.84
2	0.103	0.211	0.446	3.22	4.61	5.99
3	0.352	0.584	1.00	4.46	6.25	7.82
4	0.711	1.06	1.65	5.99	7.78	9.49
5	1.15	1.61	2.34	7.29	9.24	11.1
6	1.64	2.20	3.07	8.56	10.6	12.6
7	2.17	2.83	3.82	9.80	12.0	14.1
8	2.73	3.49	4.59	11.0	13.4	15.5
9	3.33	4.17	5.38	12.2	14.7	16.9
10	3.94	4.87	6.18	13.4	16.0	18.3

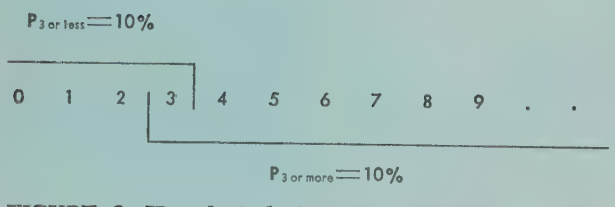

FIGURE 2: Hypothetical situation explaining the choice of f- and n-values for calculating upper confidence limits.

Table IV: Simplified Confidence Calculator

Failures	Upper Limit (t/m>Table)			Lower Limit (t/m<Table)		
	0.95	0.90	0.80	0.80	0.90	0.95
0	—	—	—	1.66	2.305	2.99
1	0.051	.106	.223	2.99	3.89	4.74
2	0.355	.53	.825	4.28	5.30	6.30
3	0.82	1.10	1.17	5.50	6.70	7.75
4	1.36	1.74	2.29	6.70	8.00	9.15
5	1.97	2.43	3.09	7.90	9.25	10.50
6	2.61	3.15	3.90	9.10	10.55	11.85
7	3.28	3.89	4.73	10.25	11.75	13.15
8	3.98	4.65	5.60	11.40	13.00	14.45
9	4.69	5.45	6.45	12.50	14.20	15.70
10	5.45	6.20	7.30	13.65	15.40	16.95
11	6.15	7.00	8.15	14.80	16.60	18.20
12	6.90	7.85	9.05	15.90	17.80	19.45
13	7.70	8.65	9.90	17.00	18.45	20.65
14	8.45	9.45	10.8	18.15	20.15	21.90
15	9.25	10.30	11.7	19.25	21.30	23.10
16	10.05	11.15	12.5	20.35	22.45	24.30
17	10.85	12.00	13.4	21.45	23.60	25.50
18	11.66	12.80	14.3	22.55	24.75	26.70
19	12.45	13.60	15.25	23.65	25.90	27.90
20	13.25	14.50	16.15	24.75	27.05	29.05

Or suppose you want to calculate the MTBF needed for 90 per cent probability of no failure on the same mission. In that case, you write:

(18) $$P_s = 0.9 = e^{-t/m}.$$

Table II (or any standard e^{-x} table) gives you the value of t/m for $P_s = 0.9$, which turns out to be 0.104, or about 0.1. Therefore, m equals $10t$, and you need an MTBF of 500 hours.

When t/m equals 1, the probability of no failure is 0.367. In other words, when equipment is operated for a time equal to its MTBF (m), you have only slightly better than a one-third chance of complete success. The moral is obvious: If you want trouble-free equipment life, the MTBF must greatly exceed the operating time.

When t/m equals 0.12 or less, you don't have to use a table. Instead you can apply the approximation:

(19) $$P_s \cong 1 - t/m,$$

which has very little error.

THE POISSON DISTRIBUTION

THE TERMS of the Poisson distribution series (*Equation 15*) give the exact probabilities 0, 1, 2, . . . failures. For instance, the probabilities of exactly one, two, three, and four failures are, respectively:

(20) $$P_1 = e^{-t/m}t/m, \quad P_2 = e^{-t/m}(t/m)^2/2!,$$
$$P_3 = e^{-t/m}(t/m)^3/3! = e^{-t/m}(t/m)^3/6,$$
$$P_4 = e^{-t/m}(t/m)^4/4! = e^{-t/m}(t/m)^4/24.$$

To find the probability of exactly four failures in an operation of 280 hours at an MTBF of 100 hours, for example, you write:

(21) $$P_4 = \frac{e^{-280/1000}(280/100)^4}{24} = 15.36\%.$$

This exact probability and others can be read directly from Molina.[3] Most reliability problems, though, can be solved with cumulative Poisson distribution data, which are also given by Molina.

If you use Molina's tables, you must remember that they represent the summation of the upper end of the series and not the lower. They therefore give the probability of "x or more" failures rather than the more customary "x or fewer" cumulative probabilities. To convert from one to the other, you only have to recall that the sum of the whole series equals unity:

(22) $$P_{x \text{ or more}} = 1 - P_{x-1 \text{ or less}}.$$

The values of cumulative probalities for $x-1$ or less are plotted in the so-called Thorndike chart (*Fig. 1*).

THE CHI-SQUARED DISTRIBUTION

MTBFs CAN BE derived from statistical test data or calculated from previously determined inputs. Since they will be estimates no matter how precise the tests or the calculations, any MTBF contains a certain amount of error. Like any statistical parameter, the estimated MTBF (and its error) will also vary from test to test. This variation follows the chi-squared distribution curve. You therefore can use the chi-squared equation to assign a confidence figure to your estimate that gives the probability that the estimate lies between two particular values on the curve.[4] Or, if you want to calculate the "best estimate" MTBF, you can assume a high and a low confidence value, compute the MTBF for each, and then derive the mean.

(3) Molina, "Tables on Poisson's Exponential Binomial Limit"; Van Nostrand, '42. Use Table I for exact probabilities, substituting t/m for a and n for c, and the second set of tables for comulative Poisson-distribution data.

(4) Confidence figures can also be found from Molina's table or the Thorndike chart, but the chi-squared equation is easier to use.

Table III (which is derived from the chi-squared cumulative probability) gives the percentage points of the chi-squared distribution in terms of degrees of freedom (f) and the probability of a chi-squared value greater than the tabulated value. It yields the same values for t/m as the Poisson cumulative-probability tables or the Thorndike chart if its entries are interpreted as twice the t/m values, its probability figures as confidence values that the t/m entries are larger than shown or (for $1-p$) less than shown, and the degrees of freedom are interpreted according to:

(23) $$f = (n + 1)2,$$

where n is the number of failures.

For example, take the case of a 600-hour test in which three failures have occured. Enter *Table III* at $f = 8$, given by:

(24) $$f = (n + 1)2 = 8$$

The column under 0.1 shows that there is a 90 per cent chance that t/m is less than 6.7. (Be sure to divide the table entry by 2.) The column under 0.9 shows that there is a 90 per cent chance that t/m is greater than 1.1 (if we set $n = 2$, $f = 6$). The lower and upper limits for m therefore are:

(25) $$m_{LL} = 600/6.7 = 89 \text{ hr MTBF},$$
$$m_{UL} = 600/1.1 = 544 \text{ hr MTBF}.$$

To find the best estimate, divide the test time by the number of actual failures:

(26) $$m = 600/3 = 200 \text{ hr MTBF}$$

You will have noticed that, to find the upper limit for m, we used $f = 6$ and $n = 2$ instead of $f = 8$ and $n = 3$. To understand the reason for this substitution, assume a high and a low value for m and the following situation:

- During the time of test, the high value of m may result in zero, one, two, or three failures, with a 10 per cent chance that the maximum of three failures will occur.
- The low value of m may result in three or any greater number of failures, but there is still only a 10 per cent chance that there will be exactly three failures.

Figure 2 illustrates this situation, which shows:

(27) $$P_{3 \text{ or more}} = 1 - P_{2 \text{ or less}}.$$

$P_{2 \text{ or less}}$ can be read directly from *Table III*.

Experience shows that even highly trained engineers find it difficult to keep in mind all the conversion steps involved in a confidence calculation even when they use the chi-squared tables. *Table IV* is a simplified confidence calculator that solves this problem by automatically performing all the required conversions.

For example, assume you want to know the upper and lower limits of MTBF to 90 per cent confidence for $t = 800$ hours and $n = 4$ failures. For these values, *Table IV* gives $t/m > 1.74$ for the upper limit and $t/m < 8$ for the lower. You now can write:

(28) $$m_{UL} \leq t/1.74 \leq 460 \text{ hr MTBF},$$
$$m_{LL} \geq t/8 \geq 100 \text{ hr MTBF}.$$

In other words, you can be 90 per cent confident that the MTBF is less than 460 hours and more than 100 hours. The best estimate (at about 50 per cent confidence) is 800/4, or 200 hours MTBF.

FURTHER REFERENCES

Ryerson, "Reliability Testing Theory Based on Poisson Distribution;" 4th Natl. Rel. & Qual. Control Symp., IRE, '58. ■ *F. Thorndike, "Cumulative Curves for Poisson Distribution;"* Bell System Tech. J., *Oct. '26.* ■ *G. Snedecor, "Statistical Methods;" Iowa State.* ■ *Chorafas, "Statistical Processes in Reliability Engineering;" Van Nostrand, '60.*

Digital Circuit Design

IN VEHICLE-BORNE electronic systems, semiconductors are being used wherever possible. Only in high-power and high-frequency stages and where the environment is more than the solid-state devices can take is the electron tube still being used. In fact, today's trend to digital circuits in aerospace vehicles has only been made possible by the semiconductor.

Transistors and solid-state diodes are particularly well suited to digital circuits, serving essentially as on-off switches in the form of pulse generators, drivers, and logic gates. The number of transistors available for digital circuits is enormous. The time spent in searching the literature for the ideal transistor for a specific application might be better spent in designing and evaluating a circuit that uses a standard type (particularly as the "ideal" type probably will be superseded within six months). Picking a transistor that meets the needs of a maximum number of circuits in a design makes for a minimum of time and money spent on component tests and evaluation, life tests, and spec writing. The standard transistor may not be the best for all circuits, but if it is properly chosen few extra components (in terms of the total system population) will be needed to make up for its below-optimum performance. This penalty will prove small in comparison with the advantages of designing around a single transistor.

Nine circuits cover most digital designs. Although we developed them to meet specific requirements, they provide a general background for the design of digital circuitry for computers as well as other equipment.

* Hughes Aircraft Co., Culver City, Calif.

PULSE CIRCUITS

IN OUR *one-shot pulse generator,* Q2 is a normally off output transistor that is triggered on when an input at C2 triggers Q1 off (*Fig. 1*). The rigging action of L1 and C1 when Q1 is off drives Q2 into saturation; the feedback diode D1 holds Q1 off independently of further input changes. As L1 and C1 ring, Q2 conducts in saturation until the voltage at the collector of Q1 reaches a peak. Then the base drive to Q2 stops, Q2 comes out of saturation, and Q1 turns on again, further driv-

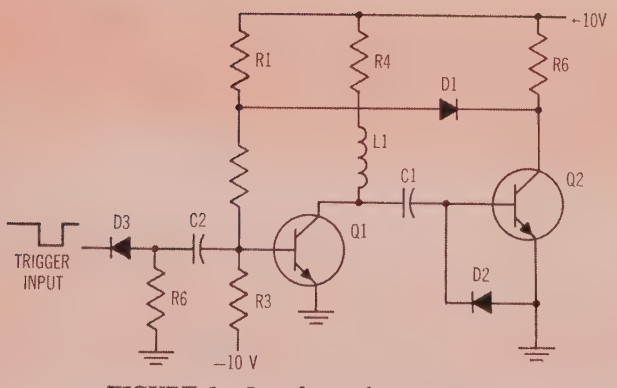

FIGURE 1: One-shot pulse generator.

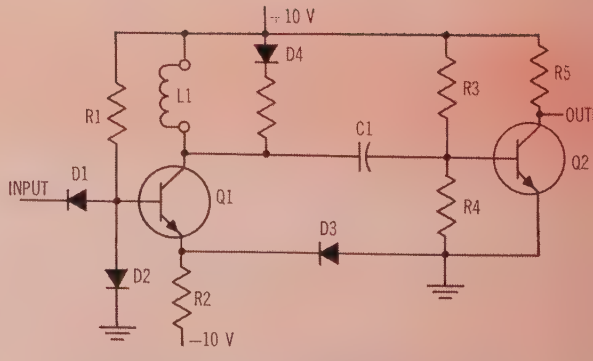

FIGURE 2: Non-saturating pulse generator.

by Donald S. Kelly, *Member, Technical Staff, Advanced Computer Circuits Group, Hughes Aircraft Co.**

ing Q2 off. After a lapse determined by the recharging of L1, the cycle may be repeated.

The output-pulse thus is determined by the values of L1 and C1. This approximation improves as R4 decreases but is limited by the peak voltage tolerable at the collector of Q1. This limitation can be removed by modifying the L1 charging circuit. As the LC time constant determines the pulse width, the output width is independent of any power-supply variation and less affected by component variation than that of any RC or L/R timing circuit.

This circuit can generate pulses with widths of 0.5-1200 usec and output currents from zero to 250 ma. Typical output rise time is less than 0.1 usec, with a 0.1-usec delay from input to output.

• *Non-Saturating Pulse Generator* (*Fig. 2*)—This circuit is a popular variant of the one-shot pulse generator of *Figure 1*. As shown in *Figure 2*, it has no feedback path from Q2 to Q1, but that is not what makes it different. Diodes D2 and D3, in combination with R2, bias Q1 into the normally-on state. Q1 is not driven into saturation—the emitter current is controlled, and once L1 is charged, the collector of Q1 is at +10 V. R3 and R4 bias Q2 so that it is just off (about 0.4 V forward bias for a silicon transistor). When a negative input appears at the input, Q1 is turned off, and Q2 is turned on by the ringing action of L1 and C1.

The pulse shape is controlled as in the circuit of *Figure 1*, except that the biasing arrangement reduces the circuit delays to less than 20 nsec. This reduction in delay and delay variation is important for critical timing systems (e.g., the clock pulse tracks on a magnetic drum).

The other output characteristics of this circuit are quite similar to those of the pulse generator of *Figure 1*. Pulse gating, desirable for many gated clock-pulse amplifiers, can be done either at the input or by providing another path for the L1 current, such as another transistor. This second transistor is turned on only when no output is wanted at a particular time.

• *Voltage Comparison Circuit* (*Fig. 3*)—This circuit accurately detects the zero crossovers of a sine wave. It can be used as the input circuit from the clock pulse track of a magnetic drum. When quiescent, both Q1 and

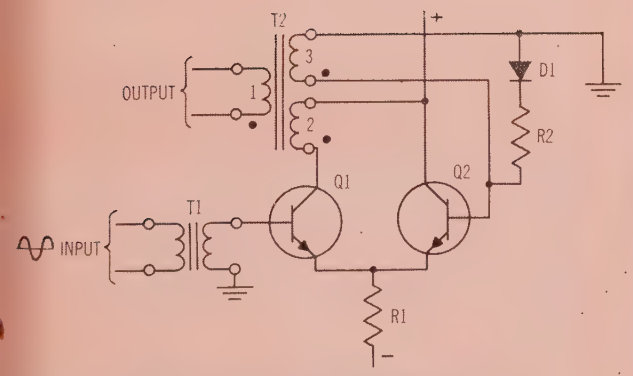

FIGURE 3: Voltage comparison circuit.

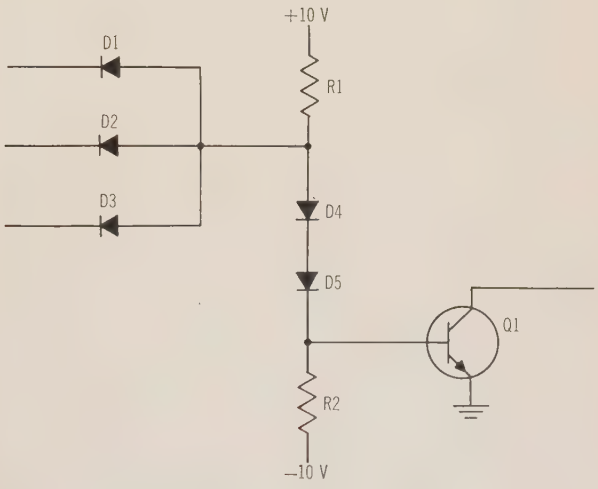

FIGURE 4: "Nor" circuit.

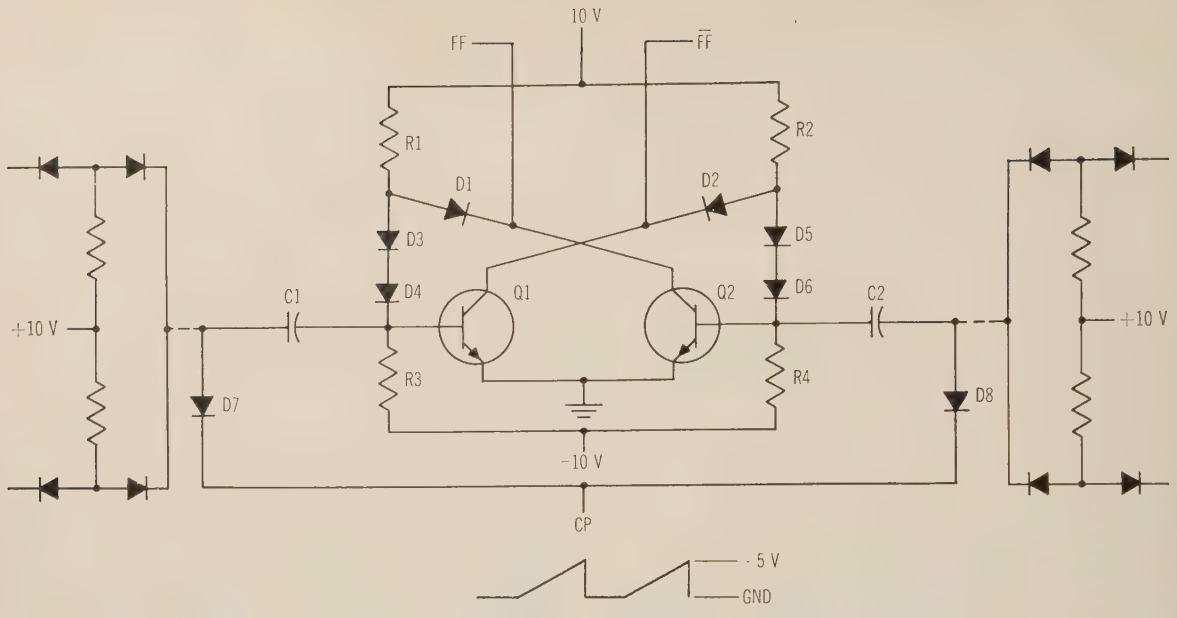

FIGURE 5: Flip-flop.

Q2 share the current flowing through R1. For accurate detection of the zero crossings of the input wave, the current balance must be controlled by matching the base characteristics, by providing emitter resistors, or by some other method. In this case, matching is relatively easy and remains independent of I_{co}, since both bases are returned to ground through a low-DC-impedance transformer.

As the input drives the base of Q1 positive and negative, the relative current-sharing changes, inducing a voltage in winding 2 of T2. This voltage is coupled back to the base of Q2 in a direction that heightens the current imbalance. The voltage at T2 then is regenerated, and the result is a very fast rise output pulse.

If the input crosses zero in a negative direction, the voltage at the collector of Q2 rises. When coupled to winding 3, it back-biases D1 further, increasing Q2's collector voltage. The output pulse amplitude is then limited only by the stray capacity at the load and the output and by the energy stored in the transformer.

Because of the stray capacity, the output tends to ring. This ringing drives winding 3 in a negative direction, forward-biasing D1, which then clamps the transformer swing and provides a current path.

Small output for positive inputs

When the input changes in a positive direction, D1 forward-biases, clamping the output as before, even though the cross-coupling is still in effect. The result is a rather small output for positive inputs and a large output for negative inputs. The relationship of output amplitude to input polarity can be modified by changing the direction of the diode. The output pulses can be used to trigger the pulse generators of *Figures 1 & 2*.

The output pulse can be made to detect a crossover within the match of the transistors. Typically, the offset voltage should be less than 10 mv; if you have been careful, it should be less than two millivolts for a reasonable transistor match. An ideal transistor for this application is the FSP-2, whose base characteristics are normally matched to five millivolts.

When this circuit is used as a clock-pulse read-trigger circuit, its delay variations naturally depend on the output amplitude of the drum signal, but a typical figure would be less than 10 nsec. The transformers are easy to design; a core material of Ferroxcube C is usually adequate.

LOGIC CIRCUITS

A *NOR CIRCUIT* in the form of a one-transistor logic gate can perform all the functions usually required in the arithmetic and control sections of a computer (*Fig. 4*). Normally, this circuit drives and is driven by, similar circuits. The logical "one"-state occurs when the transistor is saturated; the "zero"-state is the transistor cutoff.

If any of the diodes D1, D2, and D3 is connected to a similar gate whose transistor is saturated, the output transistor is cut off. If the inputs are *A*, *B*, and *C*, and the output is *O*, the Boolean-algebra expression for the logic function that is performed and that suffices for all logic operations is:

$$O = \overline{A + B + C} = \overline{ABC}.$$

A flip-flop can be made by arranging two of these circuits so that the output of each drives the input of the other. If a flip-flop with delay is required, as in the carry flip-flop of a serial adder, one of these can be arranged to drive another on special transfer pulse command, providing an arbitrary delay.*

• *Flip-Flop* (*Fig. 5*)—This circuit has few parts and is designed for relatively low dissipation in a computer with moderate operating speeds. Its basic DC design is similar to that of the "nor" circuit of *Figure 4* and is compatible with it.

Either of the two level diode gates in *Figure 5* is as-

* This approach was successfully used in the Hughes Mark I Polaris guidance computer. As only one circuit is required, the design can be completed quickly and brought to a high level of perfection. However you need more components than you would for specialized designs for each logical function. The serial adder in particular is much more complex with this approach than it is with normal diode gating.

sumed to be in the logical "one"-state—defined for this system as a positive voltage, or rather as availability of current from one of the gating resistors. When the clock pulse input is close to ground, all of this current flows through the clock pulse diodes D8 and D9. As the clock pulse starts up, the resistor current charges one of the capacitors. The charging current flows through R3 or R4 without affecting the state of the flip-flop.

Clock pulse falls rapidly to ground

When the capacitor is fully charged, the clock pulse reaches its peak and falls rapidly to ground. This quickly discharges the capacitor, and the large current that is generated turns off the transistor to which the capacitor is connected. Some charge remains on the capacitor after it is turned off, holding the transistor off until the other transistor can overcome the output capacity and turn on. The clock pulse now stays close to ground while the new flip-flop state propagates through the logic, and the new states of the diode gates are correct.

This circuit is being used in a system that operates at about 80 kc. It can be used at up to about 300 kc before the power dissipation becomes too great. Voltage margins are 40-50 per cent, and dissipation is about 50 mw.

• *Clock-Pulse Generator* (*Fig. 6*)—This circuit drives the flip-flop of *Figure 5*. The basic control is provided by the circuitry connected with Q1. Q2 and Q3 provide power output. (Both the square wave and the pulse input of *Figure 6* are generated by the pulse circuitry described earlier.)

As long as the square-wave input remains at ground, the emitter of Q1 is grounded, too. Q2 is held at the edge of saturation with the output 0.8 V above ground. When the input square wave goes positive, C2 starts to charge from the current in R1, which is controlled by the Zener-diode voltage.

As the capacitor charges, the emitter of Q1 rises, forcing up the voltage on C1. This is a large capacitor, and its voltage does not change appreciably during the clock pulse cycle. As a result, the voltage across R1 is kept constant, so that C1 charges linearly. This voltage rise is translated to the output through the two emitter followers Q1 and Q2. It is linear to about two per cent.

Linearity is desirable because the rate of change of this voltage controls the charging current in the triggering capacitors of the flip-flop. Any deviation from linearity means that the charging current will exceed the minimum requirement, making the design of the flip-flop more difficult and less efficient.

Rise time held to less than 0.06 usec

When the end of the positive half of the square wave is reached, Q3 is pulsed on. Simultaneously, C2 discharges through D1. Since Q3 is driven deep into saturation, the large capacitor discharge current can be handled, and the clock pulse's rise time can be held to less than 0.06 usec, while currents on the order of 0.5 amp are being handled.

At the end of the time for which Q3 is held on, the output of Q1 has fallen to the point where Q2 can again hold down the output. During this half-cycle of the square wave, C1 is recharged, and the cycle can then be repeated.

• *Low-Power Flip-Flop* (*Fig. 7*)—This circuit, like the one of *Figure 5* is a very popular triggering design and is being used in a space probe. Its operating frequencies are on the order of five kilocycles or less. The power drain is less than five milliwatts.

To understand how this circuit works, assume that Q1 is saturated so that Q2 is turned off. Then the anode of D1 is biased at about ground by R5 and the anode of D2 is biased at about +10 V. If a negative input is applied at the common point of the two capacitors, D1 forward-biases before D2. In fact, the

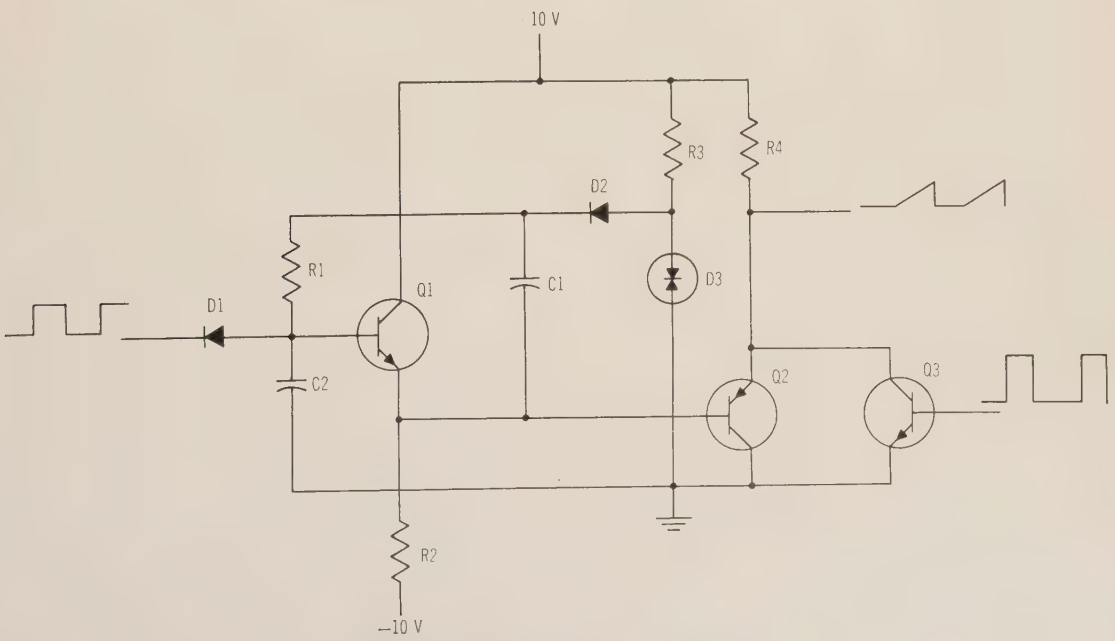

FIGURE 6: Clock-pulse generator.

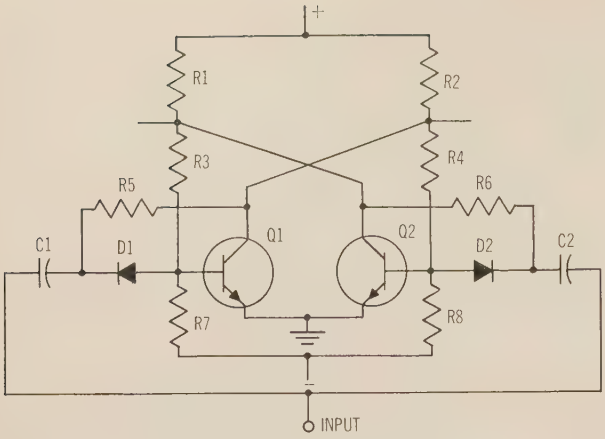

FIGURE 7: Low-power flip-flop. Power drain is less than five milliwatts.

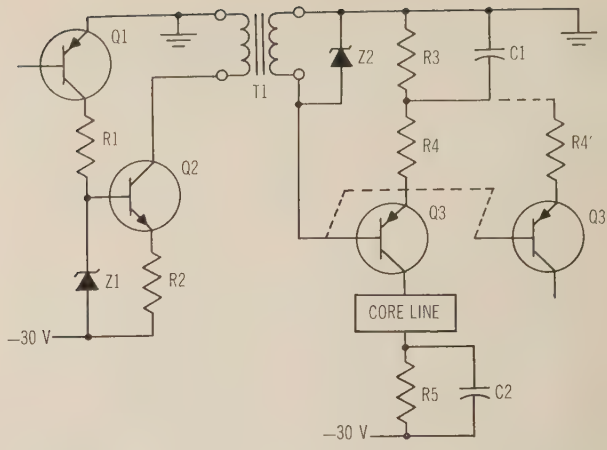

FIGURE 8: Core driver. Dashed lines show connections of four output transformers used in one system by Hughes.

input amplitude is chosen so that D2 will not forward-bias.

When D1 forward-biases, Q1 is turned off. The cross-coupling turns on Q2, reversing the state of the flip-flop. This type of complementing flip-flop has the input equation

$$Q_n = Q_{n-1}\overline{I} + \overline{Q_{n-1}}I,$$

where I is the input. It can be used to perform standard logic operations. Delay can be built in by making the logic circuit gate a clock pulse into the input instead of triggering the input directly.

The frequency response is rather limited, but merely because of power and because the input capacitors must be charged at the clock rate.

POWER OUTPUTS

OUR *CORE DRIVER* provides a pulse output of several amperes of current while the output transistor dissipates several tens of watts (*Fig. 8*). The major problem with this type of circuit lies in the DC stabilization of the output transistor—any leakage current will seem like a small signal and eventually disturb the output.

Q1 and Q2 represent two stages of preamplification. The output current of Q2 is stepped up through the transformer, which keeps the base impedance of the output transistor low.

As each pulse is amplified by Q3, a voltage is built up across the R3-C1 circuit. The direction of this voltage is such that Q3 is back-biased. If the output pulses are required at a particular rate, the voltage across R3 can be predicted. This voltage helps to back-bias Q3 when it is supposed to be off, and in combination with the back swing of T1 it is enough to stabilize Q3.

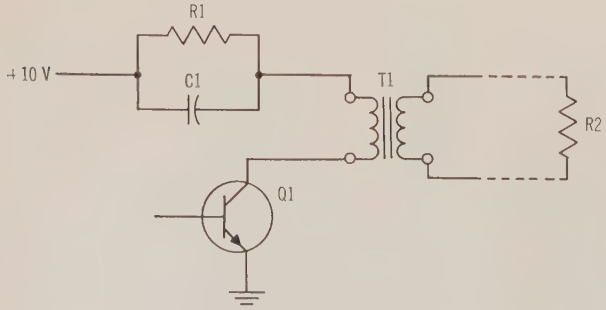

FIGURE 9: Line driver.

In a system with a 12-usec read-write cycle, a two-microsecond pulse, and a pulse amplitude of one ampere, four of these output transformers are used with complete stabilization. The combination R5-C2 serves as a fuse for the core line in case the transistor output is shorted to ground or the transistor fails.

• *Line Driver* (*Fig. 9*)—This circuit is used for communication between two sections of a computer spaced, say, 500 ft apart. This distance requires a balanced wire transmission line with transformer coupling if ground loops are to be prevented and information is to be provided at the required rate (about 100 kc). When pulse information is transmitted through a transformer at this rate, an inefficiently low exciting inductance is required if the transformer is allowed to recover completely between pulses. (The termination of the transformer is determined by the characteristics of available cabling.) The amplitude of a particular pulse then normally depends on how many pulses immediately precede it, which makes decoding difficult.

C1, R1 for short-circuit protection

For pulse output, Q1 is saturated for some length of time. C1 and R1 normally do not affect the circuit much, but are included for short-circuit protection.

However, if the time constants C1-R1 equal L1/R2, where L1 is the exciting inductance of T1 and R1 equals R2, a "constant-resistance network" results. The leading edge of any pulse across R2 then is a constant independent of any previous events in the circuit and equals the supply voltage. This independence holds true regardless of pulse width and repetition rate and is demonstrated to within two per cent for a sequence of 51 zeros followed by a sequence of 51 ones.

To take advantage of this constant amplitude, DC restoration must be used. However, since transmission is via a balanced line, another transformer must be included on the receiving end whose characteristics can be included in the value of L1.

Potting, Embedment and Encapsulation

by C. Glenn Clark, *Materials & Processing Engineer, Space Technology Laboratories, Inc.**

IN THEIR electric, physical, and thermal properties, the insulating compounds used for potting, embedment, and encapsulation naturally must be compatible with the circuit materials they enclose and with the operating environment of the equipment (*Table I*). The important effects these compounds—particularly those with high dielectric constants and dissipation factors—have on electronic parts must be carefully considered in the package design. Casting, for example, is best suited to hermetically sealed parts.

PACKAGING EFFECTS

CARBON RESISTORS can be potted or embedded very satisfactorily at temperatures below 125 deg C. Under five megacycles, no special circuit design provisions are needed, and derating normally is unnecessary. Above five megacycles, the ratio of high-frequency to DC resistance is considerably less for a potted or embedded resistor than for one operating in air. Potting and embedment generally extend resistor life, even under overloads.

- *Fixed-film resistors* remain stable and retain close tolerances when potted, so long as the insulating compound doesn't make direct contact with the pyrolytic film.
- *Wirewound resistors* should not be potted or embedded, because of their high hot-spot temperatures. Hot spots of over 200 deg C would damage the insulating compound.
- Wax-covered *capacitors* are not suitable for potting or embedment. Some glass capacitors are coated with silicone oil, which can contaminate the insulating resin.

Below 85 deg C, paper, mica, tantalum, and ceramic capacitors can be potted or embedded with safety; at higher temperatures, abnormal leakage currents occur. Capacitors above 10-15 uuf are not affected by potting or embedment. Below 10 uuf, capacity increases because the insulating compound replaces air as the dielectric. Dielectric loss in the compound increases the capacitor's loss factor.

- *Vacuum tubes* are not recommended for potting or embedding. Their heat may cause hot spots that destroy the insulating resin and shorten tube life. Glass vacuum tubes in particular are sensitive to potting and embedment. During temperature cycling, differences in the coefficients of expansion of the glass and the insulating compound cause the glass to crack. This effect can usually be counteracted by precoating strain-sensitive parts with a layer of silicone rubber that vulcanizes at room temperature.
- *Transistors* and other *semiconductor devices* can be potted or embedded without adverse effects if they are adequately sealed, with the exception of glass diodes, which behave as do glass vacuum tubes.
- *Inductors*—Both Q and L change after potting or embedment. The external capacitance of the inductor increases—an effect that can become significant at high frequencies when the conductor operates near self-resonance.

These packaging effects follow a consistent pattern for any given design and can be predicted by casting in the insulating compound before building the prototype. To cushion the effects of insulating-compound shrinkage, inductors with strain-sensitive cores can be precoated with a layer of silicone rubber that vulcanizes at room temperature.

* Space Technology Laboratories, Inc., Box 95001, Los Angeles 45, California. This article is based on a study made for USAF.

Packaging Terms

Embedment Complete enclosure of electronic parts or circuit subassemblies within a casting resin. All voids and interstices between the parts are filled. The volume and shape of the embedment are defined by a removable mold, which is separated from the casting after the resin has solidified.

Potting Embedment in which the mold remains an integral part of the unit.

Encapsulation Complete enclosure of electronic parts or circuit subassemblies with a conformal coating by dip-coating or some other surface application method.

Impregnation Application of a casting resin to tightly built devices (e.g., coil windings). Penetration of the resin eliminates all internal voids, and a completely solid assembly results. Impregnation may be used together with embedment or encapsulation.

Casting Resin Generically the synthetic resins used in embedment, encapsulation, potting, and impregnation.

• *Wire-Gages* up to AWG 42 (four mils diameter) withstand differential expansion between wire and insulating compound. Finer wires usually break. Solid bare wire or enamel-covered wire is better for hookups—stranded wire and plastic sleeving trap air in the casting.

• *Insulation* should be inert to the solvent action of the insulating compound and to the high temperature of the curing process. Certain materials, such as the adhesives on pressure-sensitive tape and the plasticizers in flexible polyvinyl insulation, inhibit the cure of the casting resins and should be avoided.

• *Materials* not wetted by the insulating compound, including tetrafluoroethylene, trifluorochloroethylene, polyethylene, and the silicone compounds, can be embedded, but they will not bond to the insulating compound. Large unbonded areas crack when cycled at low temperatures. These "non-stick" materials therefore should be used as little as possible.

• In *coating* parts, do not reduce the wall thickness of the casting below 1/16 in. in an effort to keep down weight. Lesser thicknesses usually mean inadequate strength and only moderate moisture resistance.

• In *mounting* the final casting, adhesive bonding or mechanical clamping can be used. Studs, nuts, and sleeves may be cast in the unit together with the electronic parts. For quick repair and testing, use a mounting that makes it easy to remove or replace each cast module. Terminals, plugs, and multiple connectors also can be cast into the module, and wire leads can be brought directly through the casting wall. The modules can then be interconnected by cables, etched circuitry, or wire matrix.

THERMAL FACTORS

AS THERMOSETTING insulating compounds polymerize exothermically, and the effect of the heat they generate must be considered (*Table II*). Since the compounds have low thermal conductivities, the temperatures in the casting will rise—in some cases, causing cracking of the casting, bubbling, and damage to heat-sensitive electronic parts like germanium diodes and tantalum capacitors. To compensate for this heat and minimize the temperature rise, use fillers, heat sinks, or metallic conductors to soak up or bleed off unwanted heat. Keep the mass of the insulating resin small.

The removal of the heat developed in operation by potted or embedded parts is probably the greatest problem of package designer. Unless this heat is dissipated, hot spots will appear and damage the part, the casting, or both.

Unfilled insulating compounds have thermal conductivities of 3×10^{-4} to 5×10^{-4} cal/sec/sq cm/deg C/cm. Adding powdered filler materials to the basic insulating compound increases thermal conductivities up to three times. If the conductivity is still too low, a heat sink can then be cast in the module.

The specific heat of insulating compounds ranges from 0.2 to 0.5 cal/deg C/gm, and the coefficients of linear thermal expansion range from 3×10^{-5} to 20×10^{-5} in./in./deg C (as against the range 10^{-5} to 3×10^{-5} in./in./deg C typical of the metals used in embedded or potted electronic parts and circuitry). The stresses of differential thermal expansion can crack castings or break parts. This differential can be reduced by adding fillers with low thermal coefficients to the insulating compounds. Elastomeric, flexibilized, and plasticized insulating compounds can move, thus relieving stresses.

There's some volumetric shrinkage of the insulating compound—from one to 16 per cent by volume—during curing or cooling when a change of state from liquid to solid occurs. If the dimensions of the final casting are critical, molds may have to be oversize to compensate for shrinkage.

Table I: Typical Electric and Physical Test Requirements for Insulating Compounds

	Requirement	Test Method
Electric		
Dielectric strength	275-325 V/mil	ASTM D 149-55T
Dielectric constant	2.8-8.5	Mil-C-16923, 4. 4. 7
Dissipation factor	0.003-0.7	Mil-C-16923, 4. 4. 7
Volume resistivity	10^{8}-10^{16} ohm/cm	Mil-C-16923, 4. 4. 6
Arc resistance	15,000 V @ 0.060 amp for xx sec	ASTM D 495
Thermal		
Thermal conductivity	2.5×10^{-4} – 3.5×10^{-4} cal/sec/cm²/deg C/cm	Mil-C-16923, 4. 4. 1
Linear coefficient of thermal expansion	2×10^{-4} – 3×10^{-4} in./in./deg C	Mil-C-16923, 4. 4. 9
Heat distortion	0.01 in. max. deflection @ 66- & 264-psi loads	ASTM D 648-56T
Resistance to heat	0.6% – 7.0% max. weight loss	Mil-C-16923, 4. 4. 1
Thermal shock	10 cycles, 30 min @ 90-155° C, followed immediately by 10 min at −55° C	Mil-C-16923, 4. 4. 1
Inflammability	self-extinguishing	Mil-C-16923, 4. 4. 1
Mechanical		
Shrinkage from mold dimensions	less than 1%	ASTM D 551-41
Specific gravity	depends on material	ASTM D 792
Tensile strength	depend on material and application	ASTM D 638-58T
Compressive strength		ASTM D 790-58T
Hardness		Shore ½
Flexural strength		ASTM D 790-58T
Impact strength (Izod)		ASTM D 256-56T
Elongation & modulus of elastisity		ASTM D 638-58T
Water absorption	0.1%-1.0% weight gain in 24 hr	ASTM D 570-57T
Effect of acid, alkali & solvent	loss in 7 days, depending on material and application	ASTM D 543-56T
Machining qualities	depends on application requirements	
Clarity	depends on application	

The period after the mixing of an insulating compound during which the compound remains workable depends on the ambient temperature and the compound's mass, configuration, and chemical nature. This "pot life," which ends when the compound becomes too viscous, varies from a few seconds (for a foam-in-place system) to several days or longer (for a high-temperature epoxy system). From a manufacturing standpoint, long pot life is desirable. Pot life can be measured directly or estimated from the curing kinetics data.

Production considerations make long curing at high temperatures undesirable—ovens are tied up for prolonged periods and lead time is increased. Extended cures also increase the possibility of thermal damage to electronic parts. However, long cures at moderate temperature may produce castings with a more homogeneous molecular structure (i.e., one with fewer built-in stresses).

SELECTION OF COMPOUNDS

TABLE III lists the properties of compounds used for potting, embedment, and encapsulation. However, final selections should not be based solely on this or other tables of properties (which omit certain peculiarities of materials and effects of processing techniques) but should be made only after a study of the literature on specific compounds and after consultation of the manufacturer.

- *Hot-melt materials* like wax and asphalts are cheap, have very good electric properties, and can be removed easily by remelting. Remelting does not affect the material properties, and pot life is practically unlimited. Because of their poor resistance to high ambient and hot-spot temperatures, their high shrinkage, and their lack of structural strength, however, hot-melt materials have been superseded by thermosetting plastics (phenolics, polyesters, epoxies, polyurethanes, and silicones).
- *Phenol-formaldehyde resins* are cured by a condensation polymerization. Water is a byproduct of this process, and vacuum cures at high temperatures are needed to remove the water and assure void-free castings. Corrosion may occur, and shrinkage during curing is high. The electric and mechanical properties of the finished casting are fair.
- *Polyester* casting resins are usually unsaturated and dissolved in monomeric styrene. The styrene acts as a diluent to lower viscosity and as a cross-linking agent.

Shrinkage is high—up to 10 per cent by volume. Wetting, and thus adhesion, is poor. The exothermic heat can be quite high. Most polyester-styrene resins used for casting are filled to reduce shrinkage and exothermic heat.

- *Organopolysiloxanes*, or *silicones*, are available as fluids, gels, elastomers, foams, and solventless thermosetting resins. The addition of a catalyst starts the polymerization. A heat cure is usually required.

Silicones retain their physical and electric properties at temperatures of 260 deg C for intermittent duty and 204 deg C for continuous duty. Their ozone resistance is good, and their thermal conductivity is relatively high.

Solventless silicone resins have long pot life and low initial viscosity. Long high-temperature cures are needed, and air and organic materials retard curing. Thermal shock resistance, solvent resistance, and adhesion to surfaces are low.

The use of these solvent resins generally is limited to electric impregnation for Class H service. However, small castings can be made when fillers are used.

Silicone elastomers, or rubbers, that vulcanize at room temperature are very useful for potting and encapsulation. They can be used by themselves or as cushioning layers over pressure-sensitive electronic parts and under a rigid thermosetting compound.

Silicone rubber makes an excellent mold for casting thermosetting resins. Shrinkage during curing and exothermic temperature rise are negligible. Both high- and low-temperature resistence are excellent. The electric properties are good over a wide temperature range. Adhesion to surfaces is almost nil, but can be improved with a primer.

- *Polysulfide elastomers* are widely used for sealing and potting electric connectors for aircraft and missiles (an application covered in Mil-S-8516). Their initial viscosity is high, and air removal is difficult. Thorough curing after the addition of a lead peroxide catalyst is

Table II: Exothermic Data for Resins before and after Encapsulation of Resistors[1]

Resin	Rated Resistance (CK)	High-Frequency-to-DC Resistance Ratio[2]											
		A + 3 Megacycles		A + 10 Megacycles		A + 30 Megacycles		A + 60 Megacycles		A + 120 Megacycles		A + 240 Megacycles	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Castiplast 11	4.7	1.0095	1.0046	1.0084	0.9963	1.0057	0.9573	1.0045	0.8719	0.7198	0.6453	0.4702	0 2801
	10	1.0259	1.0063	1.0193	0.9992	1.0027	0.9206	0.9593	0.7924	0.6196	0.5161	0.4327	0 2053
	47	0.9980	0.9413	1.0016	0.9130	0.9305	0.6642	0.8169	0.4413	0.2990	0.2415	0.3185	0.0814
	100			0.9539	0.7488	0.7814	0.4678	0.6069	0.3175				
Epocast 3	4.7	1.0084	1.0029	1.0013	1.0022	0.9985	0.9845	0.9630	0.9355	0.8333	0.7368	0.4978	0.3396
	10	1.0361	1.0124	1.0161	1.0174	1.0061	0.9708	0.9457	0.8915	0.6954	0.6844	0.4448	0.2687
	47	0.9711	1.0029	0.9569	0.9535	0.9320	0.8158	0.7868	0.6194	0.5393	0.4294	0.3551	
	100			0.9480	0.8482	0.8770	0.5783	0.6056	0.4011				
Eccofoam[3]	4.7	1.0198	0.9981	1.0071	1.0069	0.9929	0.9963	0.9633	0.9560	0.8416	0.8111	0.4943	0.4600
	10	1.0173	1.0108	1.0205	1.0175	1.0056	0.9991	0.9279	0.9451	0.7871	0.7756	0.4175	0.4040
	47	0.9919	1.0196	0.9813	0.9984	0.9316	0.9204	0.8573	0.8072	0.6532	0.6761	0.3224	0.2754
	100			0.9256	0.9240	0.7913	0.7245	0.5815	0.5578				

(1) Physical encapsulation dimensions were 1⅜ in. in length and one inch in diameter. (2) All values are averages of three samples. (3) Foam density was held to 20 lb/cu ft.

slow—up to 48 hours at room temperature. Resistance to weathering and adhesion to surfaces are superior. Flexibility is retained over a wide temperature range.

• *Plastisols* are particles of polyvinyl chloride suspended in an ester-type plasticizer. Fillers and stabilizers are usually added. Since liquid plastisol must be heated to 300-350 deg F to fuse it to a solid elastomer, it is limited to temperature-resistant electronic parts and assemblies.

• *Polyurethanes* are produced by the reaction of a diisocyanate with "active" hydrogens like those in polyols (polyesters, polyethers, and castor oil). Onc cured, they are strong and tough. Abrasion resistanc thermal and mechanical shock resistance, and adhesic to surfaces are high.

Polyurethane foams may be rigid or flexible. They a useful because of their low weight (2-20 lb/cu ft) an because they foam in place. In view of their low therm conductivity, however, they are not recommended fo the potting or embedding of parts that generate sub stantial heat. The mixing, pouring, and gelling of poly urethane foams should be completed under a fume hoo

Table III: Properties of Potting and Encapsulation Ma

	ASTM	Hot-Melting Materials				Silica-Filled	
		Micro-crystalline Wax	Oxidized Asphalt	Silica-Filled Asphalt	Gel-Type Compound	Styrene-Polyester	Epoxy
Electric							
Dielectric strength (V/mil)[C]	D149	500	500	500	500	425	425
Dielectric constant							
At 60 cps	D150	2.5	2.7	3.9	2.3	3.7	3.8
At 1000 cps	D150	2.5	2.7	3.9	2.3	3.7	3.6
At 100,000 cps	D150	2.4	2.6	3.6	2.3	3.6	3.4
Dissipation factor							
At 60 cps	D150	0.005	0.014	0.02	0.0005	0.01	0.02
At 1,000 cps	D150	0.008	0.012	0.02	0.0005	0.02	0.02
At 100,000 cps	D150	0.001	0.006	0.01	0.001	0.02	0.02
Surface resistance (ohms/cm²)							
Dry	D257	10^{16}	10^{16}	10^{16}	10^{16}	10^{15}	10^{15}
After 96 hr @ 95 deg F (90% RH)	D257	10^{16}	10^{16}	10^{16}	10^{16}	10^{11}	10^{13}
Volume resistance (dry, ohm-cm)	D257	10^{16}	10^{16}	10^{16}	10^{16}	10^{15}	10^{15}
Mechanical							
Tensile strength (psi)	D638					10,000	9,000
Elongation (per cent)	D412						
Compressive strength (psi)	D695					25,000	16,000
Flexural modulus of rupture (psi)	D780					10,000	12,000
Izod impact strength (notched, ft-lb)	D236					0.3	0.4
Shore hardness	D676						
Penetration @ 77 deg F (mils)	D5	12	30	16	200		
Shrinkage during cooling or curing (per cent by volume)		16	9	6	3	6	3.5
Physical							
Specific gravity	D71	1	1	15	0.94	1.6	1.6
Min. cold flow (deg F)	D792	170	140	220	185		
Softening or drip point (deg F)	D36	185	200	300	200		
Heat distortion temperature (deg F)	D648					230[F]	165[F]
Max. continuous-service temperature (deg F)		170	140	220	185	250	250
Coefficient of thermal expansion per degree F @ 10 deg F (× 10 deg F)	D696					206 x 10^5	202 x 10
Thermal conductivity (btu/sq ft/hr/deg F/ft)		fair	good	good	fair	$0.193	$0.29
Cost per pound		$0.10–0.30	$0.05	$0.10	$0.40	$0.25	$0.50

(A) In most cases, these values can be modified by changing the composition of the compound. (B) Diamine-cured. (C) Based on short-time tests of ⅛-in. specimens. (D) For six lb/cu ft. (E) For 10 lb/cu ft. (F) Some compounds have distortion temperatures of 300 deg F or higher.

since toxic diisocyanate gas may be produced during the reaction.

Thin polyurethane coatings are valuable as encapsulants for electronic circuitry. They react much like polyurethane foam, except that water must be kept out of the reaction to prevent bubbling. Solvents are added to reduce viscosity. These coatings have high gloss, high abrasion resistance, and good weathering resistance.

The use of polyurethane elastomers for potting is increasing. Toughness and abrasion resistance are outstanding, but the reactants must be kept dry. Even moisture in the air may cause bubbling in the casting.

• The *acrylic* family is made up of monomers and polymers of methacrylic acids and their derivatives. Castings of these materials have excellent optical properties and clarity. Curing is started by catalysts, and considerable exothermic heat is produced. For this reason, special precautions are necessary when acrylics are used for anything except sheets and small castings.

Molecular oxygen retards the cure, and shrinkage of the monomer in the mold is high (15-21 per cent). Shrinkage and exothermic heat can be reduced with

Rigids	Flexibilized Epoxies			Liquid Elastomers			Rigid Polyurethane Foams		
Silicone	Epoxy Polysulfide (50-50)	Epoxy Polymide (50-50)	Epoxy Polyurethane (50-50)[B]	Polysulfide	Silicone	Polyurethane[B]	Plastisol	Prepolymer	One-Shot
350	350	430	640	340	400	350	200		
3.7	5.6	3.2		7.2	3	3.2	5.6	1.05	1.07
3.6	5.4	3.2	4.9	7.2	3	7.3	4.9	1.06	1.06
3.6	4.8	3.1		7.2	3		3.6	1.04	1.02
0.008	0.02	0.01		0.01	0.005	0.08	0.12	1.004	0.004
0.004	0.02	0.01	0.04	0.01	0.004	0.09	0.1	0.003	0.002
0.01	0.06	0.02		0.02	0.003		0.12	0.003	0.001
10^{15}	10^{12}	10^{14}		10^{11}	10^{13}		10^{10}	10^{12}	10^{12}
10^{15}	10^{15}			10^{10}	10^{12}		10^{10}	10^{12}	10^{12}
10^{16}	10^{12}	10^{14}	10^{14}	10^{11}	10^{14}	10^{12}	10^{10}	10^{14}	10^{14}
	1,300	4,600	6,000	300	275	4,000	2,400	110	340
13,000	30		10	450	200	150	300		
8,000		7,000						35	400
0.3		8,300							
	40D		80D	45A	35A	90A	80A		
	3	3	6	1	2	4.5			
1.8	1.2	1.0	1.2	1.2	1.1	1.1	1.2	0.1[D]	0.16[E]
1.8									
300			100						
460	225	175	250	200	350	210	150	165	250
404×10^5	404×10^5	404×10^5	1010×10^4		1028×10^4	1010×10^4		109×10^5	109×10^5
0.23			0.77		0.13		0.09	0.02	0.02
$2.75	$0.90	$0.30	$0.10	$0.85	$4.25	$1.30	$0.30	$1.75	$3.00

casting syrup (partially polymerized monomer prepared by controlled heating with a catalyst).

• Most *epoxy resins* used for potting and embedment are made by reacting epichlorhydrin with bisphenol A. The resulting materials are generally amber-colored and range from low-viscosity liquids (5-9 poises at 25 deg C) to solids.

The pure resins are of little use. Polymerization, or curing, is required to solidify them and make them useful. Epoxies can be cured at room temperature, but optimum properties usually result from curing at high temperature.

The properties of the cured addition polymers depend on the curing agent. There are no byproducts, and the shrinkage during curing is low. Adhesion to clean surfaces is outstanding, electric properties are good, mechanical strength is high, and thermal stability and chemical resistance are excellent. However, unmodified epoxy castings are generally hard and brittle and have poor thermal and mechanical shock resistance. The addition of fillers and flexibilizers to basic epoxy resin-curing agent systems improves shock resistance and decreases brittleness.

Many otherwise acceptable insulating compounds must be rejected because they are too difficult to mix, pour, or cure. Problems are also raised by the fact that some ingredients of insulating compounds are highly toxic and many compounds give off inflammable vapors.

Compounds of high initial viscosity are difficult to mix and practically impossible to de-air and pour into an intricate mold. Highly filled compounds settle out after initial mixing. Adding a dispersing agent reduces the settling but usually increases the viscosity too much. Agitating the casting during cure to prevent settling requires complicated jigs and fixtures.

MODIFIERS

FILLERS, diluents, flexibilizers and other materials are added to basic insulating compounds to improve or modify their mechanical, thermal, and electric properties.

Fillers are generally dry, finely ground (—200 mesh), inert materials that will not evolve gas or contaminate the basic insulating compound. Typical fillers are silica, zirconium silicate, lithium silicate, calcium carbonate, aluminum oxide, aluminum, mica, and glass. Organic and inorganic lightweight, hollow, spheroid particles are also widely used.

How much filler is used depends on the desired effect, the type of filler, particle size, and specific gravity. These factors influence the pouring viscosity of the compound and the filler's tendency to settle out of the base resin, causing stratification in the final casting.

Fillers have several important effects on basic insulating compounds:

• Fillers can reduce the coefficient of thermal expansion to match or approach the coefficients of metals embedded in a casting.

• Fillers can increase the thermal conductivity to improve heat dissipation and control exothermic heat.

• Fillers improve thermal and mechanical shock resistance.

• Fillers can be used to color-code castings and to improve their appearance.

• Thixotropic fillers like colloidal silica increase the viscosity.

• Although most fillers increase the specific gravity, lightweight fillers like hollow glass microspheres lower it.

• Filled systems generally have poor insulation resistance under high humidity.

• The reduced pourability of filled systems sometimes makes degassing of the system and the filling of intricate castings difficult, if not impossible, from a production standpoint.

• Filled castings are usually more difficult to machine.

Diluents are added to basic insulating compounds to reduce their viscosity and improve their handling characteristics. A lower viscosity also makes for heavier filler loading and better wetting of potted or embedded parts. Diluents must be used sparingly, however, to avoid loss of physical strength in the final casting. The use of solvents to dilute insulating compounds causes excessive shrinkage and degrades the final physical and electric properties.

Reactive diluents like allyl glycidyl ether, phenyl glycidyl ether, and octylene oxide are widely used in epoxy compounds. They contain reactive epoxy groups that bind chemically to the cured resin.

Flexibilizers are used in the form of long-chain reactive epoxy-terminated natural oils. They are combined chemically with the basic insulating compound in order to:

• increase pot life and lower the exothermic temperature rise;

• improve flexibility and impact strength;

• improve temperature cycling properties by distributing the stresses due to differential expansion.

Extenders are used primarily to reduce the compound cost. They impart a small amount of flexibility, but may substantially reduce the physical properties of the completed casting.

MOLDING

WHEN DIMENSIONAL tolerances are critical, precision molds are needed for small electronic modules. Good molds are expensive to build and maintain—they may represent the biggest cost item in the potting or embedding of electronic assemblies.

Ideally, a potting or embedding mold should:

• be simple and easy to clean and assemble;

• make it easy to insert the parts that are to be embedded;

• precisely position parts during processing;

• make pouring and degassing easy;

• closely preserve casting dimensions and surface finish;

• minimize shrinkage and parting-line marks and flash on the casting;

• make it easy to eject the finished casting.

The designer can choose among many mold types using as his criteria design requirements of his module, the number of parts to be made, and mold cost. Whenever possible, the module should be adapted to simple mold procedures.

Molds can be made from almost any material that can hold liquid. Aluminum is easily machined, but does not wear well. Steel works very well, but its initial cost is high. Teflon and silicone rubber are useful because of their "self-releasing" properties, but they distort under temperature cycling. Teflon coatings are sometimes applied to metal molds to combine the dimensional stability of metals with the non-adhering property of polytetrafluoroethylene.

Antenna Design

by Kenneth Finken, Robert Malech, Joseph Margolin, Eugene Shube and Eugene Torow, *Staff Consultant, Chief, Advanced Antenna Development, Vice President, Chief Mechanical Engineer & Chief Engineer, Dorne & Margolin, Inc.**

WHEN IT COMES to antennas, the designer specifies coverage (in terms of radiation pattern and polarization), system gain, impedance characteristics (as a function of frequency), operating frequency bandwidth, and very often physical size and location. Many of these parameters are interdependent. The designer must be aware of such interdependence, as well as of the theoretical limitations and effects of environment on antenna performance, if he wants to specify an antenna that not only meets the needs of his system but can actually be designed.

THEORETICAL LIMITATIONS

GAIN—The system designer usually wants as much antenna gain as possible to reduce the demands on transmitter and/or receiver. However, antenna gain is limited by the antenna dimensions. As size increases, the pattern narrows. If the energy in side lobes is neglected, the gain is given approximately by:

$$G \cong 10 \log \frac{41,253}{HV} \eta, \quad (1)$$

where G is the antenna gain (in decibels); η, the efficiency; and H and V are the horizontal and vertical plane beamwidths for a linearly polarized antenna. These beamwidths depend on the size of the aperture in each plane.

The pattern is most directional when the amplitude and phase fronts across the aperture are constant and the beamwidth is $51\lambda/a$ deg (where λ is the free-space wavelength and a is the linear aperture dimension). To narrow the beamwidth beyond this point, you can use an inverted-amplitude or phase taper. This will reduce the gain, too, since the side lobes are greatly increased. The narrowing can also be done with supergaining, but this technique has little practical value—when the antenna Q is raised to very large values, the loss increases, the useful bandwidth narrows, and the manufacturing tolerances become unmanageable.

The gain includes the effects of resistive and reflective losses in the antenna. The resistive losses are allowed for by specifying η as less than unity. Reflection losses occur when the antenna is not matched to the feed system.

Side Lobes—If side lobes must be held to a minimum, you should remember that, as the side lobes are lowered, other lobes (especially the main lobe) widen. Conversely, if the main lobe is narrowed, the side lobes tend to increase.

Bandwidth—Usually, bandwidth is measured in two ways:

- The impedance match must approximate a certain value over the band.
- The pattern must be essentially constant over the band.

There is a whole class of frequency-independent antennas with constant impedance and constant radiation patterns. However, these patterns are generally broad. Also, the antennas are large, since a resonant half-wave element at the low edge of the band is required for satisfactory performance. The lowest frequency (largest wavelength) therefore determines the antenna size.

Most of the basic antenna types have fairly constant patterns and impedance characteristics over a 50 per cent band.

The Q of an antenna must be considered together with the bandwidth. Useful antenna Qs range from 2 to about 10. Although there are elaborate matching techniques to extend the bandwidth of an antenna, it is better to operate the antenna only over its usable band—the more complex a matching network becomes, the higher are the losses in the network and the more difficult it is to build the antenna.

Coverage—Although the system engineer always wants as much gain as possible, he is often forced to specify that the antenna pattern cover very large space angles, so as to make the system attitude-insensitive. As the pattern widens, the gain is reduced.

Sometimes the attitude of a spacecraft is completely undetermined, or the vehicle may pass through a wide variety of attitudes with respect to the target station. In these cases, the systems designer would be inclined to specify a spherical pattern. If the attitude about one axis is defined, then a pattern with omni-directional coverage in only one plane is specified. Such extremely broad coverages can be achieved with low gain, single-element antennas or simple arrays of low-gain elements.

Beamwidth (and therefore the coverage) increases as the antenna becomes smaller. However, once the element is reduced to less than a half-wavelength, the pattern remains constant. A half-wavelength dipole, for instance, has an omnidirectional pattern in one plane and a figure-eight cosine pattern in the other. As the dipole length is reduced from a half wavelength to a point source, the pattern remains essentially unchanged.

Polarization—Together with pattern coverage, the

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Q Values at Mach 1 *

Altitude (ft)	Q/m² for Standard Day (lb/sq ft)
Sea level	1483
10,000	1020
20,000	681
30,000	440
40,000	274
50,000	170
60,000	105
70,000	65
80,000	40
90,000	25
100,000	16

* For other Mach numbers, multiply the values given here by m^2.

Reciprocity Theorem

The terminal impedance and radiation patterns of an antenna remain the same whether the antenna is used for transmitting or receiving.

system designer must consider the antenna polarization. If a vehicleborne antenna is to work with a ground antenna of fixed polarization, the polarization of the vehicle antenna must be compatible with that of the ground station. When the attitude of the vehicle is undefined, circular (rather than linear) polarization and omni-directional coverage should be specified. Engineers familiar with the Poynting vector will recall, however, that no radiation can occur along the polarization axis.

Impedance vs Size—As a rule, designers are anxious to use the smallest possible antenna that will give the desired performance. However, as an antenna becomes smaller than a half-wavelength, the impedance changes rapidly with frequency, and there is a sharp rise in Q. For efficient transfer of power from the feed system to the antenna and out to free space, it now becomes necessary to use many sections of matching elements, which reduce the reflective losses over the desired bandwidth. Though the dissipative loss in each matching section may be low, the total dissipative loss soon begins to outstrip the savings in reflective loss, when many sections are used. Antennas therefore, are rarely made smaller than 0.1λ.

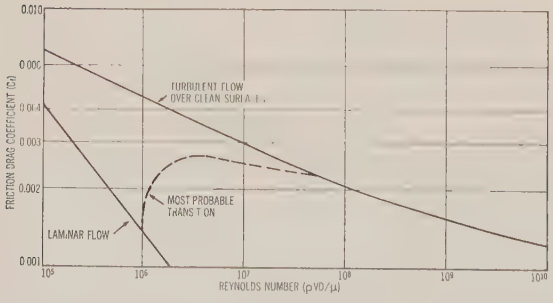


FIGURE 1: Friction drag coefficient vs Reynolds number. For turbulent flow over rough surfaces, the coefficient lies above the turbulent-flow curve shown here.

ENVIRONMENTAL LIMITATIONS

THE ANTENNA is the only system component that is always external to the vehicle. It must not only provide satisfactory transmission and/or reception for the electronics package but must also be compatible with the external vehicle contours. Therefore, antennas must be specifically designed for their vehicles and even for their locations on the vehicles.

The physical environment in which an antenna must be placed represents a basic design limitation. For antennas operating below the microwave region, the vehicle must be considered an integral part of the antenna system, since the surrounding vehicle structure affects the antenna's radiation and impedance characteristics. In the microwave and millimeter regions, the vehicle is "decoupled" from the antenna, but diffraction caused by wings, fins, nacelles, and other protuberances can cause pattern distortions. In many cases, extensive pattern studies must be made for different antenna locations on scale models of the vehicle to find the best antenna design and location. Sometimes parts of the airframe can be used as the antenna structure (e.g., the upper portions of vertical stabilizers and the fins of rocket-powered vehicles).

Atmospheric conditions must be considered when an antenna system is being specified. In the K-band region, water absorption and absorption by atmospheric gases can sharply reduce the useful ranges. Signal attenuation also occurs when systems must operate in rain and moist air (in which case circular polarization will give improved transmission).

ANTENNA TYPES

ANTENNAS can be classified into single radiating elements, arrays of elements, and reflector, or lens, antennas. Single elements generally are used when wide coverage and wide frequency bands are required. Several elements can be used in an array to provide narrow or shaped beams. A single element or a small array may also be used to illuminate a large-aperture reflector used to shape a beam.

Antennas can also be classified on the basis of their functions, which are integrally tied to frequency. In fact, frequency is the dominant element of antenna design.

Above about one gigacycle, quasi-optical antennas with apertures that are large in comparison with wavelength (e.g., parabolas, lenses, cassegrain systems, and multi-element arrays) are physically small enough for vehicle-borne systems. Below about one gigacycle, Yagis, scimitars, blades, loops, slots, and other elementary wide-beam radiators are most common. Above five gigacycles, most antennas use waveguide feeds; below five gigacycles, TEM transmission lines (e.g., coax, stripline, and triplate) prevail.

For rapid-scanning systems, electronically controlled arrays, rotatable arrays or reflector types can be used. With arrays, two or more beams can be formed from the same structure. Simple reflectors predominate where the emphasis is on low cost. For flush-mounted installations, slot arrays and surface-wave types can be used.

Various combinations of these antennas can be arrayed to produce different types of radiation patterns. Arrays can provide the high directivities of wide-aperture antennas while the excitation of the individual array elements affords some control over the amplitude and phase characteristics of the aperture excitation.

INTERFACE PROBLEMS

THE INPUT IMPEDANCE to an antenna as a function of frequency depends on antenna size and shape. It is also affected by reactive discontinuities in, and the inherent Q of, the antenna structure. To some extent, it can be controlled by varying the physical parameters of the antenna elements. However, additional matching networks must be used for systems in which the input impedance has to be matched to a system impedance over a wide frequency range. Microwave techniques for wide-band matching of a specified termination are just as applicable to an antenna, and the same limitations for matching over a frequency band apply as for any other line termination. The better the inherent match of the antenna, however, the fewer matching sections will be needed and the lower the inherent losses in the system.

When more than one antenna element is used in an array, the feed network must include suitable power dividing and phasing circuits. Also, the match of each antenna element must be maintained to preserve the required amplitude and phase distribution over the effective aperture.

A single antenna can be made to serve several systems of different frequencies if multiplexing filters are included in the feed networks. If it is small enough, the feed network often can be built directly into the antenna structure.

When several components must be connected in tandem at the antenna input, the input VSWR of the system depends on the VSWR of each component and the electric length of line between components. In the worst possible case, the overall input VSWR equals the product of all the component VSWRs. In the best possible case, the minimum VSWR of two components connected in tandem equals the ratio of the two component VSWRs.

In a system operating over a wide frequency band and containing many components connected in tandem, the input VSWR varies as a function of frequency in a complex way. The minimum VSWR will be close to one, and the maximum VSWR will be the product of the components VSWRs. A power-splitting network generally cannot be designed to provide a matched input impedance simultaneously at all terminals over a band of frequencies. Certain specialized networks (e.g., hybrid junctions) offer power splitting with all ports matched, but these devices invariably also have some undesirable characteristics.

MECHANICAL FACTORS

THE PRINCIPAL mechanical factors in vehicle antenna design are the drag penalty, vibration, other loading stresses, and sealing.

Drag is significant only for projecting antennas—flush units exert no more drag than does the skin of the vehicle. The antenna designer is concerned basically with friction drag, which predominates at low flight speeds, and with pressure drag, which becomes very important at and above high subsonic speeds. There are also many other forms of drag (e.g., induced, interference, and base drag) but because great pains are usually taken to see that antennas have no lift, are not located near other salient structures, and are streamlined, they have litle significance.

Basic to any consideration of drag is the dimensionless Reynolds number:

(2) $$R = \rho VD/\mu,$$

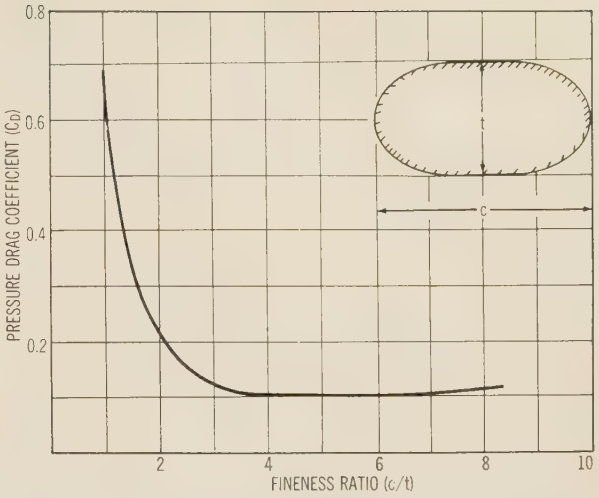


FIGURE 2: Pressure drag coefficient vs fineness ratio for constant Mach and Reynolds numbers at Reynolds numbers from 10^6 to 6×10^6.

where ρ is the air density; V, the velocity of the air (in fps); D, a length significant for the mode of fluid flow (in this case, a mean dimension of the antenna parallel to the flow); and μ, the viscosity of air in (lb/ft-sec). Before calculating drag, the flight condition must be known, so that the Reynolds number and the velocity head (Q), a measure of the impact of the airstream on the antenna, can be derived (see *Table*).

Friction drag is different for laminar and turbulent flow (*Fig. 1*).* Its coefficient (C_f) is used in the equation:

(3) $$drag = C_f QA\ lb,$$

where Q equals half the mass density times the velocity squared and A is the total wetted area of the antenna (both sides).

The pressure drag is a function both of the parameters that affect friction drag and of the antenna configuration (*Fig. 2*):

(4) $$drag = C_D QS$$

where S is the projected frontal area of the antenna.

Figure 2 is based on:

(5) $$C_D = C_f[4 + 2c/t + 120(t/c)^3],$$

where c is the chord of the antenna (or the mean length in the flow direction) and t is the thickness of the antenna. The elliptic configuration of *Figure 2* is a reasonable approximation to the shapes of many protruding antennas. Actually, there is an appreciable rise in C_D as the velocity increases.

For high subsonic and sonic speed, we can rewrite *Equation 5:*

(6) $$C_D = C_f[4 + 2c/t + 120'P'^3(t/c)^3],$$

where 'P' equals $1\sqrt{1-M^2}$, M being the Mach number.

The rapid rise in drag can be restricted to the higher Mach numbers if the antenna is swept back through an angle Δ:

(7) $$C_D = C_f[4\cos\Delta + 2c/t + 120P_\Delta^3(t/c)^4\cos\Delta],$$
$$P_\Delta = 1/\sqrt{1 - M^2\cos^2\Delta}.$$

The area affected by the drag is still the projected frontal area, but now it must be projected parallel to the air flow.

* S. F. Hoerner, "Fluid Dynamic Drag;" '58.

Vibration is probably the most important mechanical factor in antenna design. It is caused by buffeting in the airstream, by excitations originating at the attachment point to the airframe and by acoustic sources like the engine noises.

Usually these sources are so difficult to anticipate that you must overdesign your antenna to meet all conditions in an arbitrary spectrum. A relatively moderate, typical vibration resistance requirement might be ± 5 g from five to 500 cps, with an upper limit of, say, 0.036 in. double amplitude. A more demanding spectrum might go to± 10 g, and a very demanding one as high as 20 g at 5-2000 cps. Because of the resonance problem, antennas often have to be designed to withstand loadings 50-100 times the g called for by the spec for short periods.

Low mid-range vibrations seem to have the greatest effects on antennas. As all mechanical stresses must be induced by elastic distortions, the relative motion between the free end undergoing the high resonant deflection and the base is the most important factor. At the higher end of the spectrum, the impressed motion must be reduced if the g are to be kept constant.

As relative motion is normally some response factor times the impressed motion, the stresses go down as the frequency goes up. Because of the higher velocities damping is also better. Frequencies above 300 cps don' normally trouble microwave antennas.

At the very low end of the scale, the deflections re quired to maintain a given g-level become very high At 75 cps, for instance, you impose 10 g with a 0.036-in. motion. At 7.5 cps, the motion would hav to be 3.6 in. to impose the same load.

Most vehicles don't have vibrations of such larg amplitude nor are lab shaker tables equipped to simulat them. Most vibration spectra, therefore, are "clipped" at 0.10 in. double amplitude or less. The worst fre quencies for microwave antennas occur in the 80-200 cps range, with the larger antennas running into trouble at the lower end of this range.

Certain factors make it very undesirable to reduce the natural frequency of an antenna artificially to seek the "shelter" of the lowest end of the spectrum. Low natural frequencies make the antenna susceptible to flutter and other aeroelastic problems. Reducing the base section may also unacceptably compromise the side-load strength.

Raising the natural frequency also must be done with caution, since it usually requires performance tradeoffs. For example: reducing the base thickness cuts the

Basic Antenna Types

Dipole

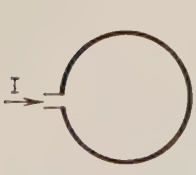
The short dipole, or doublet, provides omnidirectional coverage in the plane normal to its axis and the familiar figure-eight pattern in any plane through its axis. It is polarized in the plane of the axis of the antenna.

When the dipole is infinitesimally short (doublet), the figure-eight pattern consists of two equal circles tangent at the origin. This pattern has a beam width of 90 deg and provides 1.76 db gain over an isotropic source. As the arms of the dipole are made longer, the beam width in the plane of the axis of the antenna decreases and the gain increases. Half-wavelength and full-wavelength dipoles have beam widths of 78 and 47 deg and gains of 2.15 and 3.82 db.

When the dipole is made longer than one wavelength, side lobes appear that reduce the gain of the main beam. A maximum gain of about 5.35 db occurs when the dipole is close to 1¼ wavelengths. At greater lengths, the energy lost in the side lobes cuts the main-lobe gain. When a dipole is longer than one wavelength, perfect symmetry is extremely important.

Dipoles are often used over a ground plane to produce a unidirectional pattern. In most applications, the dipole performs best when it is a quarter-wavelength from the ground plane. Dipole antennas can generally be designed to provide a good match over a bandwidth of approximately 60 per cent.

Loop



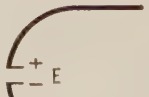
A small loop antenna is the dual of the doublet. Its pattern is omnidirectional in the plane of the loop and has a figure-eight shape in the form of two tangent circles in any plane normal to that of the loop. It also has a gain of 1.5 db, since its coverage is the same as the doublet's.

The important difference between the two types lies in their polarizations. While the doublet is polarized parallel to its axis, the loop is polarized perpendicular to this dire tion, or parallel to the plane of the loop. As the loop i creases in diameter, the beam width in the plane norm to that of the loop increases, too, and the gain in the pla of the loop decreases.

When a circular loop with uniform in-phase current two wavelengths in circumference, the gain reaches minimum of about one decibel above isotropic. Increasi the diameter of the loop decreases the gain of the lobe the plane of the loop but increases the gain of the si lobes. Many feed points are necessary to provide unifo in-phase current.

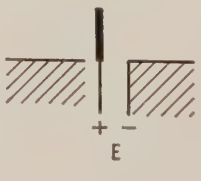
The impedance of a small loop antenna varies qu rapidly with frequency, so that this type of antenna is us ful only over fairly narrow frequency bands.

Deer Horn



A deer-horn antenna is a dipole wi its arms bent back in something li a U-shape. Its pattern is relatively co plicated, being a cross between t dipole's and the loop's. The dipole nu in the plane of the elements are fill in by radiation from the bent porti of the arms, giving omnidirectional coverage. Polarizati is in this plane. The pattern is also omnidirectional in t plane normal to the direction of the feed point (midway b tween the elements). In the remaining orthogonal pla (perpendicular to the bent portion of the arms), the co age reaches a maximum in the plane of the arms, with null along the direction bisecting the arms. All these p terns are relative and depend on the length of various p tions of the elements and the degree to which the eleme are bent back.

Stub



A stub is half a dipole fed agai a ground plane. With an infinite, f ground plane, its pattern is identi with half the dipole's, except that gain is increased by three decib because the radiation is confined

natural frequency but compromises side load strength; increasing the base thickness raises the natural frequency but lowers the electric performance.

Cavity type, or flush, antennas have fewer severe vibration problems, for their construction is more box like and there usually are no large, unsupported areas. Vibration problems with these antennas involve the adequate support of internal parts, matching sections, and the like to make sure that, when large drumming motions of window and cavity occur, the internal parts will not shake loose.

Other loading stresses that antennas must be able to withstand include side loads, ice loads, thermal loads, and loads peculiar to the particular installation. Fortunately, you can usually calculate these stresses rather simply and accurately.

Flutter must be considered for antennas exposed to an airstream. The dimensionless ratio for this factor is $V/\omega b$, where V is the local velocity through the air (for bending flutter) or the speed of sound (for torsional flutter); ω, the natural frequency in bending or torsion (in rad/sec); and b, the half-chord (in the same units of length as the velocity). When $V/\omega b$ exceeds 4 or 5 and there is a possibility (when you use bending-mode parameters) that the antenna can be exposed to the airstream at any angle of attack exceeding the stall angle, it's best to consult an aeroelasticity specialist.

Sealing against leakage of moisture into dielectric spaces must be complete for microwave antennas. Water has such a high dielectric constant (80) that the smallest amount of it in an air or dielectric space can throw the performance off entirely. The problem is so bad that sometimes the question of how to seal the antenna affects the initial design parameters.

Antennas that are taken to high altitudes and then are returned to earth are given an opportunity to "breathe." If they do so, they are sure to take in water vapor.

You can check for leaks by submerging the antenna in water and evacuating the pressure to an altitude of 60,000-70,000 ft. Any escaping bubbles would show a leak. The test must be run very carefully, for even a solid aluminum block will appear to "leak" if the water is too warm, or is aerated, or if surface dirt causes boiling.

To solve the sealing problem, many antennas are filled with foamed-in-place, low-density urethane or similar foam. The foam fills all voids and leaves little room for moisture to get in, even if the cavities are imperfectly sealed.

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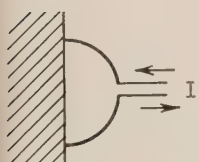
one hemisphere. When the ground plane is finite, some radiation spills into the hemisphere behind it, while the pattern maximum is at some angle above the ground plane. The larger the ground plane, the closer is the pattern maximum to the ground plane and the less energy spills behind the ground plane. Regardless of the size of the ground plane, the signal in a plane parallel to the ground plane is three decibels below that of an equivalent dipole.

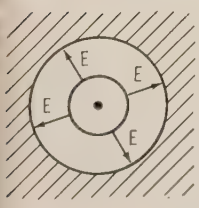
A curved or conical ground plane brings the pattern maximum closer to the plane normal to the axis of the antenna and can offset the effects of a small ground plane. A stub with a conical ground plane that has a slant height of a quarter-wavelength and an included apex angle of 90 deg provides patterns similar to a dipole's in free space. In the limit, the ground plane is folded back around the feed cable to form a choke for a dipole-antenna. The cross-section of the stub can be elongated in one direction to form a blade antenna. The feed can be part of the way up on the stub to form a sleeve-fed stub, or blade, and the structure may be shunt-fed to provide a rigid mechanical structure. All these variations considerably affect the impedance, but the patterns remain essentially the same.

Half-Loop



Half of a loop antenna can be operated against a ground plane and produces patterns very similar to the pattern of a loop radiating into half-space. A finite or curved ground plane affects the patterns in the same manner in which the ground plane affects the patterns of a stub.

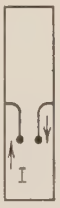
Annular Slot



As the height of a stub antenna is reduced from one-quarter wavelength, the patterns do not change appreciably, but the impedance deteriorates rapidly. The radiation resistance drops sharply as the series capacitive reactance rises, producing an equivalent high-Q antenna. This effect can be compensated to some degree by top loading. In the limiting case, the top loading is made larger and the height is cut to zero by recessing the stub in a small cavity beneath the top loading (mounted flush with the ground plane). When top loading and backing cavity are circular, you get an annular slot.

The annular slot has patterns that are essentially those of a short stub or, more precisely, of a magnetic loop. It provides the same coverage as does a conventional electric loop (modified by the ground plane), except that the electric and magnetic fields are interchanged, so that the polarization is parallel to the axis of the annular slot. As the diameter of an annular slot increases, the gain in the plane of the slot decreases in the same manner as does the gain in the plane of a loop when the loop diameter increases.

Linear Slot



The radius of a small half-loop antenna can be decreased without affecting the radiation patterns. However, the impedance of such a loop cannot readily be matched to the operating impedance of most equipment. A small cavity behind the loop improves the impedance, and the actual conductors of the half-loop can be located in the plane of the ground plane. As the backing cavity is usually rectangular, the resulting antenna is called a linear slot.

Like the annular slot, the linear one is a magnetic dipole with patterns identical to its dual, except that the electric and magnetic fields are interchanged. The linear slot is polarized in a plane perpendicular to the axis of the slot.

Most slot antennas are used with a backing cavity to limit the radiation to one hemisphere. If the slot has no such cavity and is free to radiate on both sides of the ground plane, the same pattern exists in both hemispheres.

The equivalent magnetic current on one side of the ground plane is 180 deg out of phase with the magnetic current on the other side (because of the reversal in direction of the outward normal). Any slot antenna free to radiate on both sides of a ground plane therefore always has

a null in the plane of the ground plane. Special feed systems have been devised to avoid these nulls and produce omnidirectional patterns. They are the equivalent of two slot antennas with backing cavities and require a corresponding ground-plane thickness.

Slotted Cylinder

When a linear slot is installed in a ground plane curved back from the slot to form a cylinder, you get a slotted cylinder. As the diameter of the cylinder is decreased, the patterns become omnidirectional in the plane perpendicular to the axis of the cylinder and identical with those of a small loop or a magnetic dipole whose axis coincides that of the cylinder. For greater omnidirectivity, multiple slots can be arranged about the cylinder just as loop antennas have multiple feeds to provide uniform in-phase current about the loop.

The theoretical gain of a slotted cylinder is higher than that of a loop of the same diameter because of the extended aperture along the axis of the loop. The cylindrical slots patterns therefore resemble those of a dipole of equivalent length. However, to achieve the theoretical gain, the slot has to be excited over its entire length. Because the cylinder often acts as a waveguide beyond cutoff, it may be necessary to use multiple feeds for each slot.

U-Slot

A linear slot folded back to form a U-shaped aperture is the dual of a U-shaped dipole, or deer horn. Its ground-plane effects are similar to those of a simple stub. Variations of the U-slot include an annular slot with an unbalancing strap that shorts one portion of the aperture as well as the E-slot, which has improved impedance characteristics.

Turnstile Arrays

Two dipoles that cross at 90 deg and are fed in time quadrature form the turnstile antenna. Its pattern is nearly omnidirectional in the plane of the dipoles and in any plane perpendicular to this plane, in which the signal is linearly polarized and parallel to the dipole elements. Normal to this plane, the signal is circularly polarized—clockwise in one direction and counterclockwise in the other. Elsewhere the signal has an intermediate elliptic polarization, so that it gradually changes from circular in one sense, to elliptic, linear, elliptic, and finally circular in the opposite sense. (Isotropic antennas that are circularly polarized in the same sense in all directions are quite useful for missiles and satellites that have no attitude control. However, an antenna with such a pattern is theoretically impossible, since in every radiation pattern there must be at least one null or some region of elliptic and circular polarization in the opposite sense as well as the required transitional region of linear polarization. The simple turnstile comes closest to meeting the isotropic characteristic but falls far short of the desired polarization, since one hemisphere is polarized in the opposite sense. Often the best solution is to resort to a diversity system using two separate antennas polarized in opposite senses or orthogonally and two separate receivers, and then select the stronger of the two signals.)

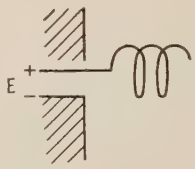
Crossed Loop

Two loops crossing at 90 deg and fed in time quadrature form the crossed-loop antenna. It produces radiation patterns similar to the turnstile array's. In the direction of the intersection of the two loop planes, the signal is circularly polarized (again in opposite senses in the two directions). In the plane normal to this axis, the pattern is omnidirectional and polarized parallel to the intersection of the two loop planes. As in the turnstile, there are intermediate conditions of left- and right-hand elliptic polarization.

An array consisting of a pair of crossed loops and a turnstile everywhere provides circular polarization in the same sense. However, the radiation pattern is that of a cardioid of revolution, with its maximum along one direction of the axis of intersection of the loop planes and a null in the opposite direction.

The equivalent of both the turnstile and the crossed loops can be constructed of slot antennas. However, the size of the vehicle in this case must be commensurate with the frequency of operation.

Helix



A conductor wound in the form of a helix on a cylindrical surface and fed against a ground plane is a helix antenna. It can radiate in several modes depending on the size of the structure and the operating wavelength.

The most useful mode occurs when the circumference of the cylinder approaches one wavelength. In this case, there is a traveling wave whose phase varies with the distance along the conductor and the currents on opposite sides of the cylinder are in phase. (There is a 180-deg phase shift because of the geometry and another 180-deg phase shift because of the traveling-wave delay.) The radiation from these in-phase currents add along the axis of the helix. The orthogonal components of current along the top and bottom of the cylinder are similarly in phase with each other but in time quadrature wth the vertical currents (because of the traveling-wave delay).

Adjacent turns of the helix have currents of similar phase and produce an end-fire effect. The result is a unidirectional, circularly polarized beam along the axis of the helix. Beam width and therefore gain can be controlled by the number of turns on the helix, which controls the end-fire directivity of the structure.

Spiral

A spiral antenna is a conductor wound in the form of a spiral on a flat plane The spiral generally has two arms emanating from a central feed point. A balanced feed provides optimum performance. As in the case of the helix, there is a traveling wave on the conductors and opposite currents are in phase in the band about one wavelength in circumference and provide in-phase circularly polarized radiation along the axis of the spiral.

The spiral is not fed against a ground plane. Its elements radiate a two-lobed pattern, with the lobes coinciding with the axis of the spiral. Generally, the spiral is located in front of a ground plane or backing cavity to produce a single-lobe pattern.

The spiral's bandwidth theoretically is very large. The lowest operating frequency is determined by the maximum diameter of the spiral, and the highest frequency is limited by the structure near the feed point. The beam widths of the patterns are relatively independent of frequency, since the major radiation occurs in the band close to one wavelength in circumference. In practice, the bandwidth is limited to about 2:1 because of the required one-quarter wavelength spacing from the ground plane and the need for a balun to provide the balanced feed. When the circumference approaches two wavelengths, higher-order modes may exist that tend to destroy the desired radiation patterns.

Note: The important classes of surface- and leaky-wave antennas have been omitted, because their suitability for aerospace vehicles has not yet been explored fully and because their design and use are so highly specialized.

Mechanical Design

by Fredrick T. Gutmann, *Development Engineer, ITT Federal Laboratories Div., International Telephone & Telegraph Corp.**

DEFORMATIONS

ACCORDING TO Hooke's law, which forms the basis of machine design, strain (unit elastic deformation under load) is proportional to stress, or force per unit area, within the elastic limit. Both elastic deformations due to working stresses and deviations of parts from their ideal geometry pose problems of mechanical design. Even the best-made gears are eccentric, links are slightly bent instead of straight, sheet-metal parts are warped or bellied. The resulting misalignments, deflections and inaccuracies must be anticipated and provision must be made for their adjustment and correction.

Three important axioms of mechanical design help you to avoid problems:

- Design for minimum restraint.
- Do not rely on gravity.
- Rotation is easier to handle than translation.

There is an interplay between deformation and tolerances. If a mechanism is mounted or moved with minimum restraint, the deformations are minimized, and the tolerances often can be loose. For example, when a four-legged mechanical module is bolted to a slightly warped base plate, there will be deformations in both base plate and module (*Fig. 1*). If the module has only three legs, mutual deformation will be avoided, though there may still be some local deformations of either legs or plate. These can be minimized if the legs are designed to allow some deflection (which also relaxes the squareness requirements for both legs and plate).

To take another example, a traveling-pen carriage, designed to move along two parallel rods guided by a pair of V-notches resting on one rod and located in plane by a flat resting on the other rod, is barely satisfactory for a stationary, level installation (*Fig. 2*). Mount it in a vibrating structure or a moving vehicle, and the carriage will lift off the rods. Restraining springs are needed to keep the carriage on the rods (with the location tolerances of the rods fairly loose so long as they are in one plane). The whole design would be greatly simplified if the carriage could be moved in an arc rather than in a straight line.

EXTERNAL FORCES

THE EFFECTS of external forces are felt even by shock-mounted equipment. Sudden shifts of a vehicle exert forces on the internal members; at the

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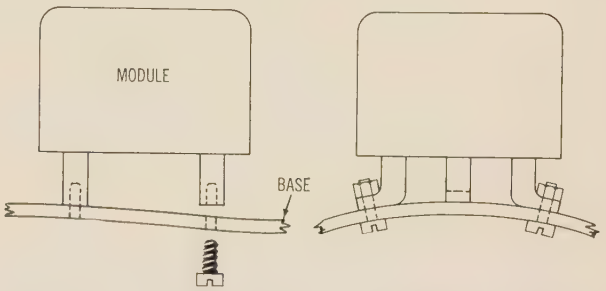


FIGURE 1: For attachment of a mechanical module to a warped base plate, three legs are better than four. If the feet of the three-legged module are bent, there is no distortion of the module.

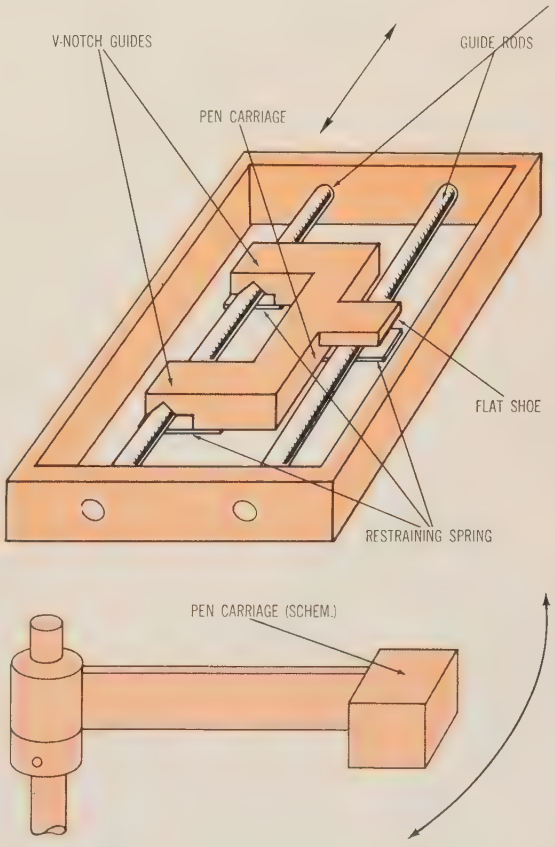


FIGURE 2: Traveling-pen carriages become much simpler when they operate in rotation rather than in translation.

Table I: Common End-to-End Shaft Couplings*

Type	Remarks
Oldham coupling	needs anti-backlash provisions
Bellows coupling	limited torsional rigidity
Universal joint	must be used in pairs
Toothed coupling	danger of backlash, allows very little misalignment
Pin coupling	cyclic errors if shafts are offset
Sleeve coupling	not recommended; rigidity over-restrains shafts

* In descending order of versatility.

Table II: Permissible Static Tooth Loading*

Diametral Pitch	Gear Material	
	Stainless Steel	Aluminum
48	53	28
64	43	24
80	35	18
96	30	16

* For instrument gears of 0.500 in. pitch diameter and 0.125 in. face width.

Table III: Pitch-Line Velocities

AGMA Quality Number	Former AGMA Class	Velocity (fpm)
8, 9	Comm. 3, 4	up to 400
10, 11	Prec. 1	up to 2000
12, 13, 14	Prec. 2, 3	over 2000

least they cause deflections of the structure. To minimize these effects, the substructures must be stiff.

While the stiffest and lightest structure is the hollow sphere, the most efficient structure when it comes to combining stiffness and usable volume is the cube. The shorter the sides of the cube are, the less will they tend to vibrate. When the sides of a cube or a prism-shaped structure are fairly long, they should be reinforced with stiffeners, which may be diagonal ribs, for instance, and should be either extruded or welded on. The corners of such a structure should be reinforced with gussets.

Vibration-absorbing structural material using a layer of high-loss plastic bonded between aluminum sheets is available in sheet form and in a number of structural shapes. In critical applications, this material may be well worth its cost.

Cantilevers should be avoided. A vibrating structure is a bad anchor for a cantilever, and any cantilever is essentially one of the tines of a tuning fork. U-brackets are far superior to cantilever brackets.

ELASTICITY

ELASTICITY in controlled form—in springs and torsion bars—can be used to good advantage. The ordinary drop compass, for instance, has a parallelogram guide made of a pair of cantilevered springs that, for the required small angular deflection, is much simpler than an equivalent, fully articulated linkage. A highly sophisticated application of an elastic member is represented by the harmonic drive developed at United Shoe Machinery, which uses a circular, flexible spline as a speed-reducer. Other examples are the recently developed Bendix-Utica spring pivots that allow almost friction-free oscillation of shafts without bearings and Hunter Spring's Neg'ator spring, which has an almost invariant spring constant throughout its extension (*Fig. 3*).

DRIVE MECHANISMS

MOTION TRANSFER generally is either positive (shafts, gears, chains, mechanical linkages) or has some slip (belts, friction drives, adjustable-speed drives).

Positive drives in most cases have an output that is a linear function of the input motion. Shaft couplings should transmit motion accurately while compensating for angular, radial, and longitudinal shaft misalignment (*Table I*). If no other type of coupling will serve and there is enough space, gears can be used to couple shafts.

Highly accurate gear drives can be designed to fit most requirements. Gear designs should follow the standards of the American Gear Manufacturer's Association (AGMA), which define the best current practice in the industry. Tooth size and gearing proportions depend primarily on the forces to be transmitted (*Table II*).

For most drives in electronic equipment, spur gears

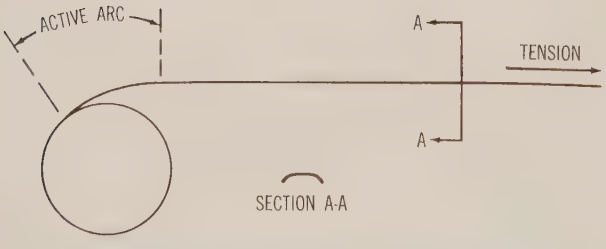


FIGURE 3: Neg'ator spring assumes a curved cross-section as it unwinds from its pulley. Its spring action is limited to the active arc, and almost constant tension is maintained.

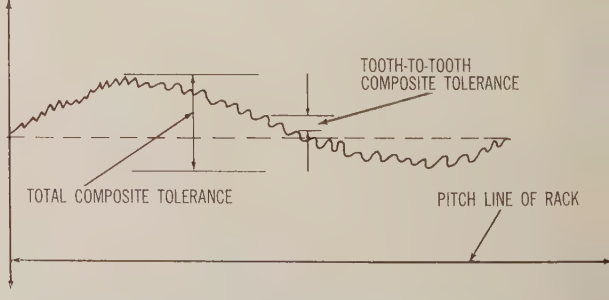


FIGURE 4: Tooth-to-tooth composite tolerance (TTCT) and total composite tolerance (TCT) of gear elements are shown by the trace of a gear center.

Table IV: Protective Finishes

Plated			Processed		
Material	Plate	Reason for Use	Material	Film	Purpose
Carbon & alloy steel	hard chrome flash (over copper)	wear resistance	Carbon & alloy steel	phosphate	rust resistance (paint undercoat only)
	chrome & nickel (over copper)	rust resistance, appearance	Stainless steel	passivated	inhibiting of electrolytic action
	chromate cadmium	rust resistance			
Copper & brass	zinc	solderability	Aluminum	anodized	Non-conducting oxide coating, colored film for appearance & color coding
	silver	conductivity			
	chromate cadmium	corrosion resistance		Brytal chromate film (Iridite)	specular reflection conductivity protective coating
Aluminum	gold flash (over copper & silver)	conductivity, solderability	All materials except stainless steel	prime & paint	protection, appearance

are used. Helical gears, whose teeth and flanks engage gradually, give quieter operation, but are more expensive and generate thrust loads. Single-pass reductions of no more than 6:1 are customary in spur and helical gear trains, but higher ratios can be used. Nonmetallic gears are also quiet but are less accurate and have less dimensional stability than do metal types.

Bevel gears are used for right-angle drives with ratios from 1:1 to about 4:1. They may be curved-tooth Zerol gears, which give quieter operation than straight-cut gears. For higher-ratio drives, worm-wheel drives and variations of hypoid drives are used. Stock ratios range from about 7.5:1 to 360:1 for worms with up to four threads.

The basic phenomena of gear accuracy and backlash are the same for all types of gearing, so that for an analysis we can turn to spur gears, which represent the simplest case.

Gear quality in the AGMA classification system is based on the total composite tolerance (TCT). Gear prices increase exponentially with the quality number. Numbers 13 and 14 can be justified for special uses only. Applications for higher numbers are off in the future (*Table III*).

Because of gear runout, the trace of the center of a gear rolling in intimate contact with a theoretically perfect rack (a gear of infinite diameter) is a sinusoidal curve (*Fig. 4*). The waviness of the curve is due to tooth spacing and thickness and profile errors. The maximum excursion of the curve is the TCT.

Backlash is not strictly a gear error as such, but, of course, it is still undesirable in reversing gear drives. In electronic applications, the designer usually is concerned only with its maximum possible value. The tighter the mesh, the less backlash—but some backlash is necessary for sliding contact of mating teeth without jamming.

Besides gear geometry, gear eccentricity (which causes periodic changes in the tightness of the tooth mesh), shaft deflection, and differential expansion between gears and mounting plates can cause backlash. Backlash can be minimized by increasing the gear accuracy, by the use of minimum gear-center distances and tight center-distance tolerances, by avoiding shaft deflections, by the use of materials with the same coefficients of expansion for gears and plates, and by mechanical anti-backlash devices.

Two concentric gears spring-loaded against each other are used in a well-known anti-backlash design. One of the gears is fastened to the shaft and the other floats. Together they grip the teeth of the mating gear in scissor fashion. The torque capacity of these gears is limited by the loading springs, and the pitch-line speed should be kept below 400 fpm.

Spur and bevel gears are often run without lubrication so long as they are lightly loaded and mating gears of different materials are used. Dry-film lubrication is recommended as a precaution, as are dust-tight

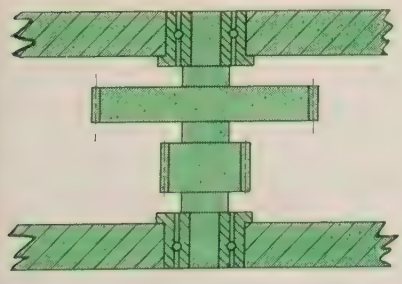


FIGURE 5: Gear and ball bearing assembly with flanged bearings and spacers to take up the thrust and position the gears.

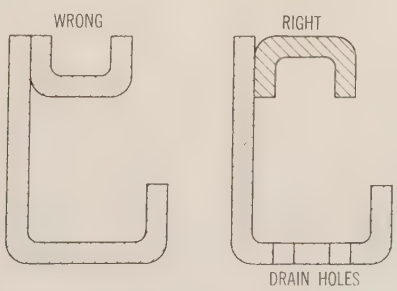


FIGURE 6: Structural design to avoid pockets in which moisture can accumulate, involves the use of drain holes.

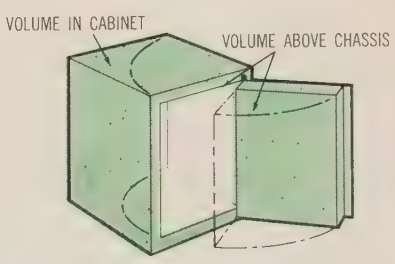


FIGURE 7: Vertical swing-out mounting for an electronic chassis. Configuration sweeps out a portion of a cylinder.

enclosures. Worm-wheel drives should be run in lubricated gear boxes.

Chain drives are seldom used in electronic equipment. They are sometimes combined with wire ropes for non-coplanar drives. Silent chain transmits motion with minimum distortion. Roller chains are affected by alternating velocity lead and lag, because the pitch circle of the sprocket is really a polygon. Plastic and bead chains can be used to transmit only nominal loads.

Parallelograms and similar linkages also form positive drives, and other types of linkages can now be synthesized to provide outputs closely approximating pre-determined laws. Backlash must be kept to a minimum in all linkages, which means there are power losses, because tight bearings and sometimes loading springs must be used.

Another kind of positive drive is the cog, or timing, belt. It is quieter than other drives, but also somewhat more elastic.

Positive drives transmit either high torque at low speed or low torque at high speed. This fits into the designs most common in electronics, where small, high-speed motors drive slow-moving elements with fairly high outputs.

Non-positive drives are of limited usefulness in electronics. V-belt drives are used for blowers and compressors, and O-rings serve as belts where slip and stretch don't matter. Flat, rubber-covered Dacron belts are available for very high speeds (up to 20,000 fpm). A limiting factor is the centrifugal force developed at the pulley. Flat Mylar belts are coming into use in tape drives. Depending on the load, the belt slip in most cases is on the order of one per cent.

Adjustable-speed drives also offer non-positive transfer of power. The ball-and-disk integrator has a constantly rotating disk as the input member, and the output speed is picked off by a ball in a cage that can be radially displaced on the disk. One type of speed changer has a rotating cone input member driving a friction wheel that can be positioned along it. To avoid excessive wear, drives of this type must not be run continuously at or near zero output speed.

BEARINGS

A NUMBER of rules apply to all bearings used in electronic equipment:

- Lubrication should last the life of the equipment (fairly easy for rolling-element bearings, somewhat more difficult for plain bearings).
- Any shaft should have no more than two bearings.
- Either bearings must be aligned with great care or self-aligning bearings must be used.

While plain bearings are simple, cheap, and do not produce electric noise, rolling-element bearings have low starting and running torques, and a built-in, prepackaged accuracy. In electronic equipment, rolling-element bearings are almost always used for high-speed drives.

The most widely used materials for plain bearings are brass, bronze, nylon, Teflon, and phenolics. The simplest plain bearing is a straight reamed hole in brass (preferably leaded). For life-time lubrication, porous, oil-impregnated bronze bushings can be used, but their surfaces should not be machined (to avoid closing the pores). The impregnating oil is affected by temperature extremes. Solid bronze can also be used in combination with a dry lubricant (usually a molybdenum compound) on the shaft.

Nylon and Teflon bearings are self-lubricating and available plain or filled with graphite or bronze. Teflon is softer than nylon but suitable for higher temperatures. Phenolics today are used mostly for ball-bearing retainer rings.

Bearings must be able to take axial as well as radial forces. The small ball bearings used in electronic equipment usually have enough thrust capacity. In gear trains and similar applications, both plain and rolling-element bearings should be flanged. Gears and shafts can then be axially retained between the bearings without additional parts (*Fig. 5*).

Air is coming into use as a lubricating or support film between mating surfaces. Air bearings are either hydrodynamic or hydrostatic. In the latter type, air is admitted through tiny peripheral holes in the bearing. Filtered air must be supplied by a compressor.

Inherently, air bearings are extremely accurate, have low friction, but low carrying capacity. They are widely used in gyros and memory drums.

CORROSION CONTROL

THE BASIC IDEA in corrosion is to cover or neutralize exposed surfaces. Some useful rules of corrosion control are:

- Avoid troughs and pockets in which condensed moisture can collect; provide drain holes (*Fig. 6*).
- Avoid contact between materials far apart on the electrolytic scale. If you can't, the larger part should be cathodic.
- Use corrosion-resistant materials for moving parts.
- Cover exposed surfaces with paint or an electrochemical or chemical finish (*Table IV*).

The variety of finishes available for corrosion protection is wide and bewildering. In the interests of economy, a few proven combinations should be selected and used consistently throughout a project. The more complex finishing problems require the attention of a specialist.

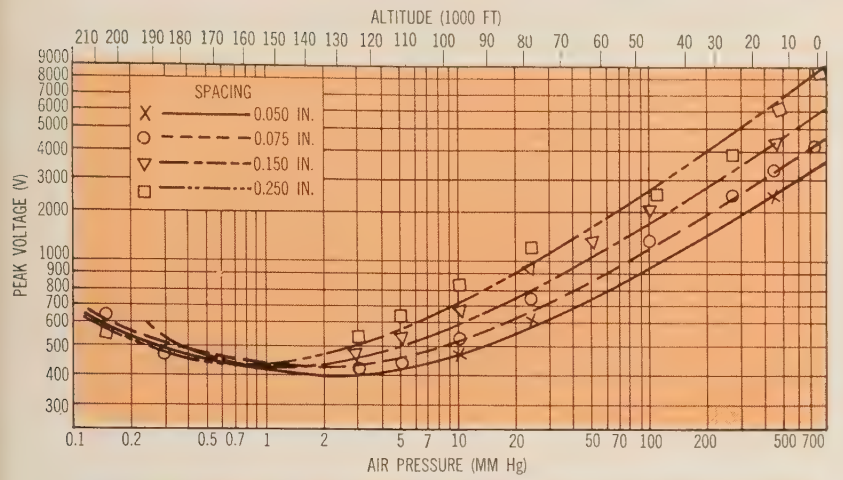
Riveted and spot-welded work has slight gaps at metal-to-metal interfaces. The chemicals used to clean metals before finishing penetrate these gaps and can't always be flushed out completely. The finishing process therefore can cause much more local corrosion than would occur if the material remained untreated.

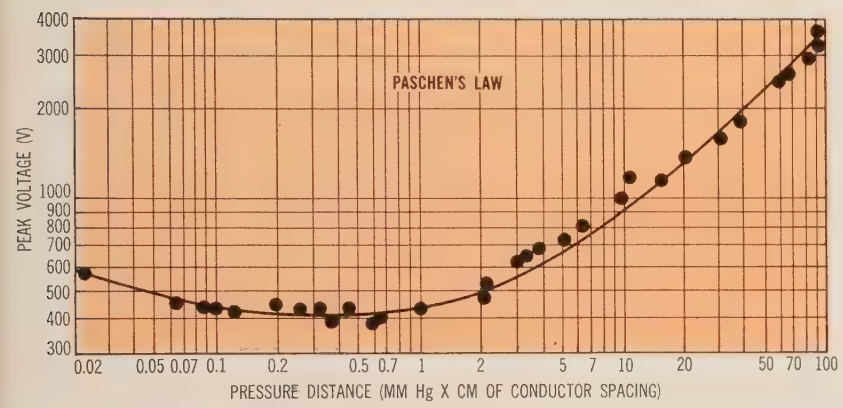
MECHANICAL PACKAGING

TO CONSERVE VOLUME, all components on a chassis or deck should be of about the same height. All the heavy components should be as close as possible to the edges of the chassis to hold deflections and vibration to a minimum. The equipment should be broken down into self-contained plug-in modules that are easy to replace. Try for an optimum balance between module size, the number of modules per chassis, and a minimum of connector pins.

In the simplest modular chassis, all circuit boards are of the same size and mate with the same conductor. Electromechanical modules carrying servo motors, potentiometers, and gear trains naturally are more complex.

Conductor Spacing in Printed Wiring*





A minimum nominal spacing of 0.05 in. between adjacent conductors or between a conductor and the edge of the board is recommended. Closer spacing should be avoided, since it makes for difficult fabrication, risks of electric flash-over, lowers the insulation resistance, and increases the capacitance coupling.

For equipment that normally operates below 10,000 ft, the data in the Table apply (though larger spacing should be used where space is available). For equipment operating above 10,000 ft, the graphs should be used. The breakdown voltage for any conductor spacing is quite low at high altitudes. Pressurization of the equipment may therefore be necessary. If it is impractical, the maximum usable voltage may be severely limited. The Graphs show the actual breakdown voltages, to which a safety factor, (which depends on the specific design) must be added. The Graph applying Paschen's Law to printed circuits gives the breakdown voltage for any pressure and any conductor spacing.

Both graphs apply for frequencies of 400 cps or less. At frequencies above 400 cps, the characteristics of the base laminate may reduce the breakdown voltage between conductors, and special allowances must be made.

*From "Military Equipment Design Practices," Bell Telephone Laboratories.

Max. Peak Voltage Difference between Adjacent Conductors (V)[A]	Min. Nominal Spacing between Adjacent Conductors (in.)[B]
0.240	0.050
241–340	0.075
341–420	0.100
421–500	0.125
over 500	0.0003 per volt

(A) For DC and AC currents of 400 cps or less. (B) The spacing between any two adjacent conductors does not necessarily apply for other conductors on the board.

The swing-out chassis looks promising for modular design (*Fig. 7*). It replaces the two slides of the common pull-out chassis with an ordinary hinge and follower cables with simple loops. However, it makes efficient layout a little more difficult, since it sweeps out a portion of a cylinder. The dead space in the cabinet of a swing-out chassis can also be used for components and circuitry, which are still easily accessible when the chassis is swung out.

The vertical chassis deck, whether swung out or pulled out, has the advantage of providing vertical air chimneys, so that fewer blowers are required per cabinet, and of making the wiring side of the chassis more accessible and fully visible.

Enough space should be left for wire runs and cables, and clamps or tie-downs should be provided. All break-outs should be logical, so that components can be disconnected in an orderly fashion. A component whose leads cannot be removed, for instance, should not be included in an overall harness but should have its own, separate cable. Follower cables (if they can't be avoided) should have either mechanical support to prevent fouling or mechanical retractors—springs built into them, external retracting mechanisms, or the like. Molded multi-conductor tapes can be used to good advantage as followers.

DESIGN REVIEW

WHEN THE PRELIMINARY design is completed, take the time to review it—thoroughly. Are all the parts you have used really necessary? Do the moving elements have enough clearance? Will the fastenings do their job? Could a different approach be used to any of the problems that have had to be solved?

Manufacturing methods must be constantly reviewed if you want to get the most for your dollar. The number of units to be built is often an important factor—it may determine whether a simple metal box should be bent and welded, machined and assembled with screws, sand-cast, made from a permanent-mold casting, or die-cast. Materials also must be closely examined.

Thermal Design

by S. K. Fenster, *Senior Engineer, Space Systems, Air Armament Div., Sperry Gyroscope Co.**

THE PROBLEM in cooling electronic equipment is to reduce the thermal resistance between the sources of heat and the sink to which the heat must be transferred. In aerospace vehicles, the problem is compounded by miniaturization and packaging, which call for light, small, and highly efficient and reliable cooling systems.

* Air Armament Div., Sperry Gyroscope Co., Great Neck, N. Y.

Heat can be transferred by conduction, convection, and radiation. Normally all three of these forms occur simultaneously in an electronic assembly, though one may predominate. It is usually best to design a cooling system around a single heat-transfer process, with the others providing a margin of safety.

There are no hard and fast rules for the choice of

Nomenclature

Conduction Heat Transfer

A	cross-sectional area of heat conductor (sq ft)
dt/dk	temperature gradient (deg F/ft)
k	thermal conductivity (btu-ft/sq ft-hr-deg F)
L	characteristic length of cooled object (ft, Table II)
Q	transferred heat (btu/hr)
Δt	temperature difference between bulk coolant and surface (deg F)

Convection Heat Transfer

h_c	coefficient of heat transfer (btu/hr-sq ft-def F)

Free Convection

C	constant dependent on shape and position of cooled object (Table III)
c	specific heat of coolant (btu/lb-deg F)
G_r	Grashof number ($g\beta\Delta tL^3\rho^2/\mu^2$)
g	gravitational acceleration (4.17×10^8 ft/hr/hr at sea level)
m	constant dependent on type of coolant flow — for G_rP_r between 10^3 and 10^9, m = 0.25 (laminar flow, usual in electronic equipment cooling); for $G_rP_r>10^9$, m = 0.33 (turbulent flow)
N_u	Nusselt number — $C(G_rP_r)^m$ for free convection
P_r	Prandtl number ($c\mu/k$)
β	volumetric coefficient of thermal expansion (deg R^{-1})
μ	viscosity of coolant (lb/ft-hr)
ρ	density of coolant (lb/cu ft)

Forced Convection (Table V)

D_o	outside diameter (ft)
G	coolant mass flux, lb/sq ft-hr, ρV)
N_u	Nusselt number — $CR_e^m P_r^n$ for forced convection
n	constant dependent on geometry and nature of flow
R_e	Reynolds number (GD/μ)
V	velocity (ft/hr)

Radiation Heat Transfer

F_a	arrangement factor (depends on the configuration of the bodies; Table VII)
F_e	emissivity factor (depends on material and surface condition; Table VII)
T_1	absolute temperature of higher-temperature body (deg R)
T_2	absolute temperature of lower-temperature body (deg R)
ϵ	emissivity
σ	Stefan-Boltzmann constant (0.173×10^8 btu/hr-sq ft-deg R^4)

Combined Heat Transfer

$\frac{L}{kA}$	conductive thermal resistance
$\frac{1}{h_cA}$	convective thermal resistance
$\frac{1}{h_rA}$	radiative thermal resistance
h_r	$F_eF_a\sigma\,(T_1^4 - T_2^4)/(T_1 - T_2)$

cooling process, but there are basic facts that can serve as general guidelines. In space, for example, natural-convection cooling is ruled out, because it depends on gravity *(Fig.1)*. Spacecraft applications would also require low power consumption, minimum weight and volume, and probably years of fault-free operation. A passive cooling system using metallic conductors to transfer the heat to radiating heat sinks that are part of the vehicle's skin meets these demands.

Because of aerodynamic heating, aircraft and missiles, though they may have the same weight, volume, and reliability requirements, cannot use conductive systems as the ultimate sink. Liquid cooling involving appreciable vapor volumes is also unsuitable, since attitude changes can expose components to the vapor and lead to overheating. Nor can aircraft and missile systems use radiation cooling as the primary heat-transfer mechanism—effective radiation requires a high temperature differential between component and heat sink. In the atmosphere, its main function is to provide a margin of safety for a design based on some other heat-transfer mode.

A correct choice obviously depends on a good knowledge of the heat-transfer capabilities of cooling methods and mediums (*Table I & Fig. 2*). Where they can be used, natural and passive cooling methods—conduction, free and natural convection, vaporization cooling, and radiation—are preferable, since they do not require pumps, fans, or blowers to aid the process of heat transfer.

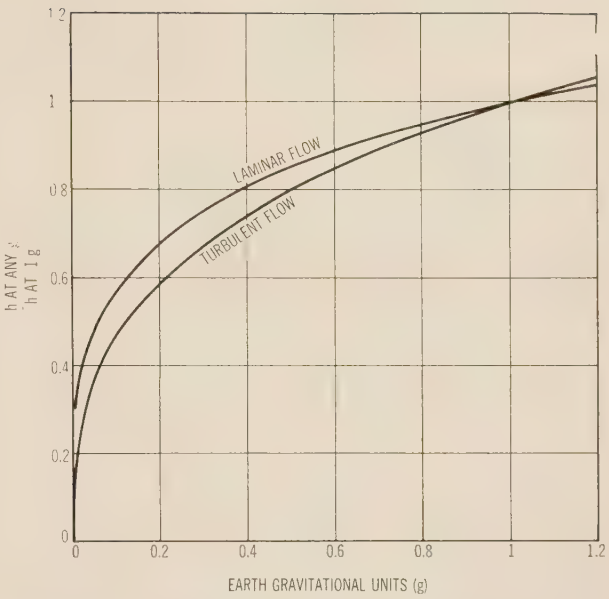


FIGURE 1: Change in convection with changing gravitational field for laminar and turbulent flow ($m = 0.25$ and $m = 0.33$, respectively).

CONDUCTION

CONDUCTION cooling requires materials with high conductivity *(Fig. 3)*, good thermal contact between surfaces, generous conduction areas, and short conduction paths. It is governed by Fourier's Law:

$$Q = -kA\frac{dt}{dx},$$

which often can be used in the alternative but not exact form:

$$Q = kA\frac{\Delta t}{L}.$$

The negative sign in the first equation shows that heat flows in the direction of decreasing temperature.

Table I: Heat Transfer Selection Guide

Mode of Heat Transfer	Heat Transfer	Remarks
Free convection + radiation in air	max: 0.5 W/sq. in. usual: 0.25 W/sq. in.	70-80-deg F temperature rise
Plastic-embedded components	max: 0.25 W/cu. in.	no metallic conductors
Forced convection by air	max: 2.0 W/sq. in.	
Direct liquid cooling by free and forced convection	4.0 W/sq. in.	70-80-deg F temperature rise
Vaporization cooling	7.0 W/sq. in. or higher	

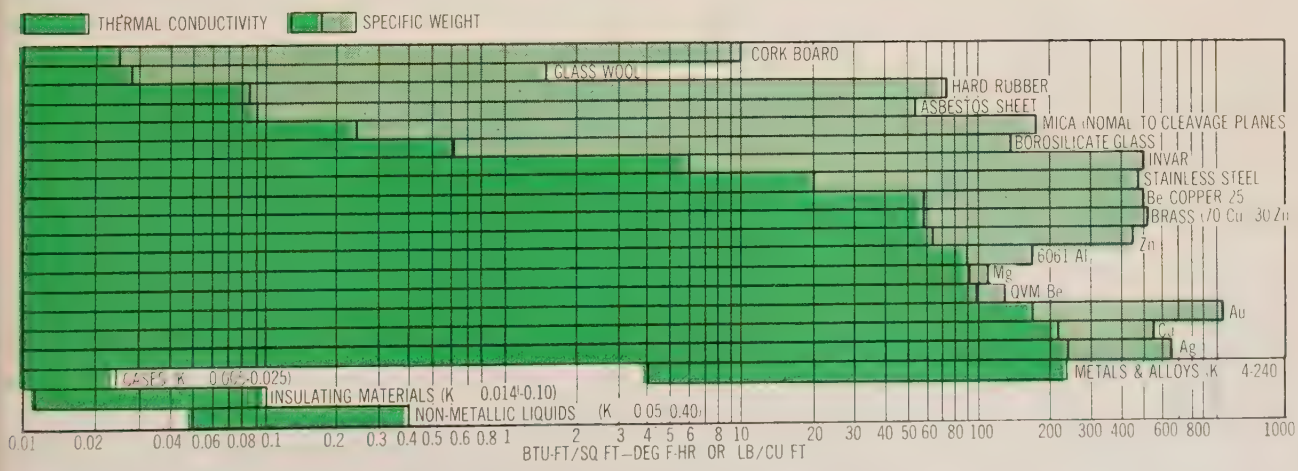


FIGURE 2: Thermal conductivity and density of materials used in electronic applications.

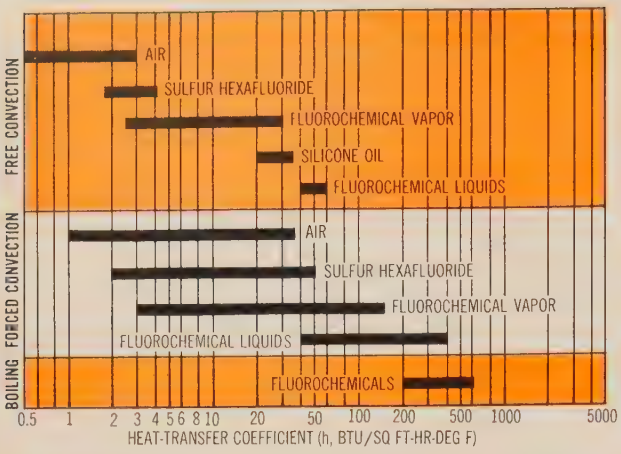


FIGURE 3: Heat-transfer ranges of air and a number of liquid coolants.

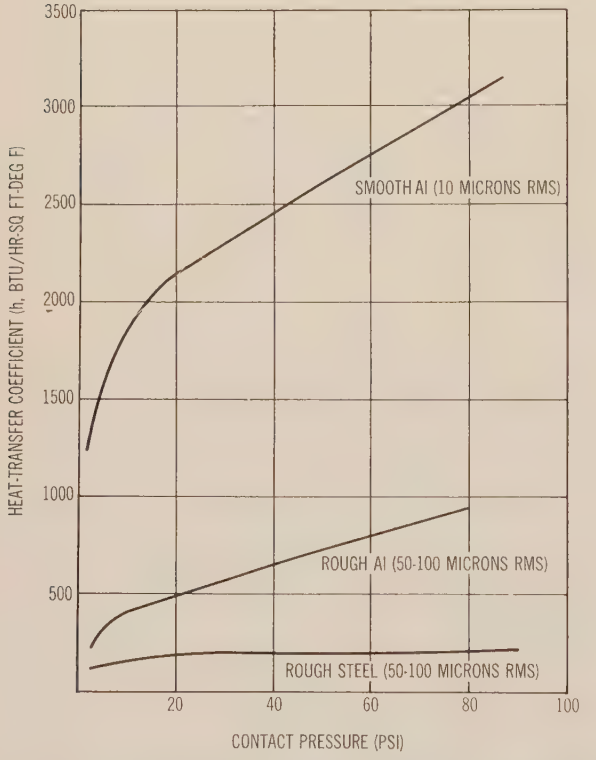


FIGURE 4: Heat-transfer coefficient vs contact pressure for flat, clean aluminum sheet and steel of differing roughnesses (given as the RMS of surface irregularities).

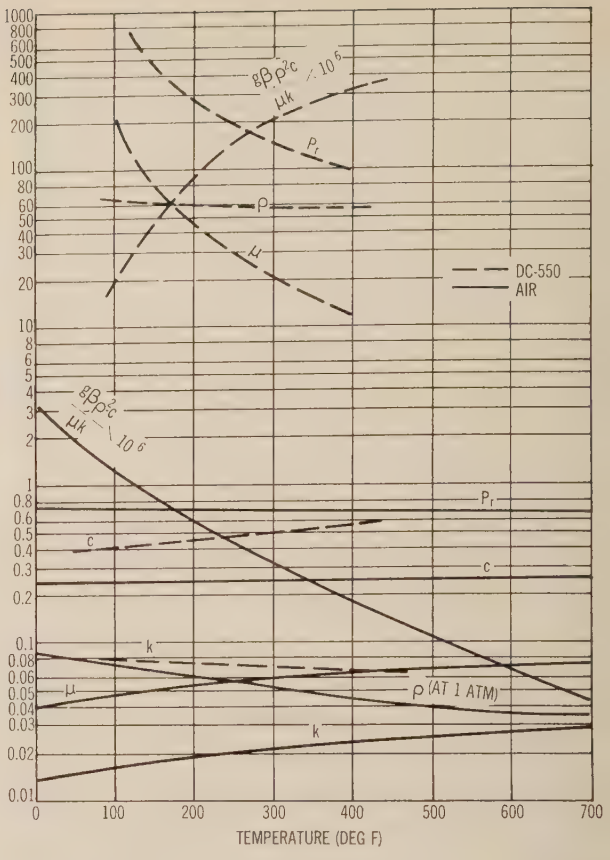


FIGURE 5: Free-convection heat transfer vs temperature for important parameters of two coolants.

Table II: Characteristic Lengths of Objects Cooled by Free Convection

	Characteristic Length (L)
Horizontal plane	length × width/(length + width)
Horizontal cylinder	cylinder diameter
Vertical rectangular plane (L < 2 ft)	vertical height
Vertical non-rectangular plane	area/horizontal width
Vertical cylinder (L < 2 ft)	cylinder height
Sphere	diameter/2

Conduction cooling is especially useful for very densely packed assemblies, in which heat transfer by other modes may be hampered. The coolant flow volumes and heat dissipating areas required for convection cooling may not be available, for example, and flow blockages are always a possibility. Radiation cooling is usually unsatisfactory in such assemblies because of the relatively low temperatures at which the components must operate and because of the poor "view" the hot bodies may have of cooler objects. (Radiation cooling is essentially by infrared waves. Since these travel along lines of sight, the hot and cool objects must be in view of each other.)

Conduction cooling can be provided by enclosing components in metal cans or spring-type sleeves connected to the chassis through low-resistance thermal paths. The outside of the chassis can then be cooled by conduction, convection, or radiation. A metallic chassis in this case can be regarded as a local heat sink for the components, but it has a finite heat capacity and must be adequately cooled.

Non-metallic chassis generally should be avoided. Potting material, unless it has unusually high thermal conductivity (approaching that of metals), should be considered as structural support only. Where more than 0.25 W per cubic inch of potted assembly must be dis-

Table III: Forced Convection Correlations

Flow and Geometry		Remarks
Flow in circular tubes, $L/D \geq 60$	$h_cD/k = 0.023\ R_e^{0.8}P_r^{0.4}$	for any fluid at $P_r = 0.7$ to 120 & $R_e = 10{,}000$ to 120,000 & with all fluid properties evaluated at bulk temperature
Flow of gases in circular tubes	$\frac{h_cD}{k} = 0.0198\frac{k}{D}R_e^{0.8}$	for gases at $P_r \cong 0.69$ $Re > 3100$
Flow of air across wires & tubes	$h_cD_o/k = bR_e^n$	R_e: 0.4–4, n: 0.330, b: 0.891; 4–40, 0.385, 0.821; 40–4000, 0.466, 0.615; 4000–40,000, 0.618, 0.174; 40,000–250,000, 0.805, 0.0239. air properties evaluated at $(t_{surface} + t_{bulk})/2$
Flow of gas parallel to smooth surface	$h_cL/k = 0.055(GL/\mu)^{0.75}$	L equals surface length up to 2 ft; for all lengths > 2 ft, L = 2 ft.
Flow of air across tube or cylinder banks—normal to staggered tubes: b = 0.33, n = 0.6; normal to in-line tubes: b = 0.26, n = 0.6	$h_cD_o/K = b(D_oG/\mu)^n$	G based on minimum-flow area, $R_e = 2000$ to 32,000; air properties evaluated at $(t_{surface} + t_{bulk})/2$
Flow of air normal to square, flat-sided tubes → □	$h_cL/K = 0.092(GL/\mu)^{0.675}$	$R_e = 5000$ to 10,000, L = diameter of tube of equal perimeter
→ ◇	$(h_cL/K = 0.22(GL/\mu)^{0.585}$	$R_e = 5000$ to 100,000

sipated, heat transfer should proceed primarily through metallic conducting paths.

Junctions in the conduction flow path should have good thermal contacts, otherwise they can present large inpedances to heat flow. Contact resistance decreases with increasing contact pressure (*Fig. 4*). Soft metals like copper and silver that are interposed between contacting surfaces flow into surface flaws under pressure, reducing the thermal resistance. Good soldered, welded or brazed joints present almost zero contact resistance. Surface anodization and silicone greases can also be used to reduce contact resistance. Components particularly susceptible to heat (e.g., transistors) require special attention. The insulating washers often used between transistors and the chassis can provide thermal conduction if they are thin enough. The spring clips for fastening transistors to the chassis give a low-impedance thermal path, and silicone grease can be used to reduce thermal resistance.

In all cases, the largest surface area of the heat-producing element should be in contact with the heat sink, and the connection path should be as short as possible, since conduction varies directly with the cross-sectional area of the conductor and inversely with the length of the path.

CONVECTION COOLING

CONVECTIVE heat transfer depends on the motion of the coolant over the surface of a body that is at a higher temperature and is governed by:

$$Q = h_cA\Delta t.$$

The convective heat transfer coefficient can be expressed as:

$$h_c = N_uk/L \quad btu/hr\text{-}sq\ ft\text{-}deg\ F_1$$

and differs depending on whether forced or free convection is used and according to the properties of the convecting fluid (*Fig. 5*) and of the surface of the hot object. (*L* is the characteristic length. See *Table II.*)

In free-convection cooling, the fluid motion is produced by density differences caused in turn by temperature gradients. The heat-transfer coefficient for free convection is experimentally correlated by

$$N_u = C(G_r\ P_r)^m,$$

where the constant C depends on the shape and position of the cooled object (*Table IV*).

Free-convection heat transfer in air can be used to cool assemblies in which the heat fluxes are less than 0.5 W per square inch of cooling surface. For higher fluxes, forced-air cooling is often used, while free-convection cooling is still used for the sink that forms the overall housing and presents a larger surface area. Above about 30,000 ft, low air density makes free convection cooling impractical unless assemblies are sealed and pressurized (usually at sea-level pressure).

For free-convection cooling, heat-dissipating components should, if possible, be mounted in a vertical plane to permit the free flow of convection currents and encourage the chimney effect. Should the uppermost elements thereafter become overheated because of high vertical gradients, then the parts can be stacked at an angle from the vertical. Rectifier plates should also line up vertically to take advantage of the chimney effect and prevent the formation of stagnant horizontal layers of coolant.

Free-convection liquid cooling is also feasible. In its simplest form, it requires a sealed assembly, with the coolant in direct contact with the components and the heat from the walls transferred in some way to an intermediate or the ultimate heat sink. Such systems generally can handle flux levels on the order of 0.5 W/sq in.

In forced-convection cooling, the flow of the coolant fluid is induced primarily by a pump, fan, or blower. This mode is often used to supplement free convection cooling, preventing hot spots. In sealed units, an internal fan or pump can be used to force the coolant through a heat exchanger cooled by an external fluid under forced convection. Among the correlations for forced-convection transfer (*Table III*), the one for the coefficient is expressed by:

$$N_u = CR_e^mP_r^n.$$

Forced convection is most effective with turbulent flow. The convective coefficient for turbulent flow can be 10-100 times higher than that for laminar flow. Laminar convection may also require several times the turbulent flow volume to transfer the same amount of heat. Turbulence can be heightened by the use of fins, vanes, baffles, or ducts.

Direct liquid forced-convection cooling systems can transfer more heat than can liquid free-convection systems. They use a pump to circulate the liquid and force it through a heat exchanger, which may be an extended surface array around which ambient air is forced, or the container walls in contact with a liquid fuel or cryogenic heat sink. After heat removal, the coolant is returned to the heat source. In direct liquid cooling systems, the coolant should be routed to flow past the temperature-sensitive components first after leaving the exchanger.

The coolants of direct liquid cooling systems must be chemically compatible with all the wetted surfaces. Many liquids are acceptable as coolants—the choice depends on the system's operating temperatures, heat loads, and internal surface chemistry, as well as on the liquid's vaporization temperature, vapor pressure, viscosity, flash point, dielectric constant, power factor, and decomposition products. Fluorinated hydrocarbons, for instance, offer good heat-transfer and dielectric characteristics and have unusually good thermal stability (*Table V*).

Table IV: Free-Convection Constant C

	At G_rP_r = 10^3 to 10^9	At G_rP_r > 10^9
Vertical plates	0.55	0.13
Long, vertical cylinders	0.50	0.12
Horizontal upward-facing plates	0.71	0.17
Horizontal downward-facing plates	0.35	0.08
Horizontal cylinders	0.45	0.11
Spheres	0.63	0.15

Table V: Properties of Fluorinated Hydrocarbon

	FC-75	Coolanol 45
Dielectric Strength (kv)	33 (176° F)	18 (185° F)
Dielectric Constant	1.86 (1-40 kc, 75° F)	265 (1 kc, 77° F)
Density (gm/cm³)	1.76 (77° F)	0.887 (77° F)
Viscosity (cs)	0.805 (77° F)	18 (77° F)
Coefficient of volumetric expansion per degree F	10×10^{-4} (av., 66°-176° F)	4.8×10^{-4} (−35° to 225° F)
Specific heat (btu/lb-deg F)	0.248 (77° F)	0.45 (77° F)
Vapor pressure (mm Hg)	760 (210°-224° F)	760 (630° F)

Table VI: Radiation Factors F_e and F_a

	Area	F_e	F_a
Parallel planes large relative to separating distance	A_1 or A_2	$\dfrac{1}{\frac{1}{\epsilon_1}+\frac{1}{\epsilon_2}-1}$	1
Completely enclosed body large relative to enclosing body	$A_{\text{enclosed body}}$	$\dfrac{1}{\frac{1}{\epsilon_1}+\frac{1}{\epsilon_2}-1}$	1
Completely enclosed body small relative to enclosing body	$A_{\text{enclosed body}}$	$\epsilon_{\text{enclosed body}}$	1

Forced-convection systems should be designed for a maximum amount of channeling parallel to the flow. Horizontal fins on the heat-dissipating components provide increased surface area as well as channeling in the main flow stream.

In indirect liquid cooling systems, the coolant does not come into direct contact with the components. Instead it is forced through passageways in the container walls. Heat is transferred to the walls by free or forced convection, radiation, and conduction, and the coolant is circulated through a heat exchanger. Coolant requirements for the indirect system are less stringent than for the direct systems, particularly when it comes to compatibility and electric properties. Air can also be used as the wall coolant in an indirect system.

CHANGE-OF-PHASE HEAT TRANSFER

HEAT CAN ALSO be transferred by a change in the physical state of a substance—by the vaporization of a liquid, for example. Highly accelerated evaporation, or boiling, causes considerable fluid turbulence and is an effective heat-transfer mechanism. The same formula applies as for convective transfer, except that h_c is higher, because of the change of phase. The high coefficients of boiling make it possible to operate cooling systems at lower temperature differentials between bulk liquid and component surface, so either the component surface temperature can be lowered or a smaller heat exchanger can be used.

In a boiling system, the coolant vaporizes on contact with heated component surfaces. Vertical channels can be used to guide the vapor upward to a heat exchanger coil above the electronic assembly. The exchanger can be cooled by forced air or other means, and the condensate returns to the container by gravity. No pump is required, but flow can be induced if necessary.

Coolants for vaporization systems should have low boiling points and high latent heats of vaporization, in addition to the characteristics required of direct liquid systems. The assembly containers must be evacuated before they are charged with the coolant, since incondensible gases can lower the heat-transfer coefficients in the heat exchanger or cause vapor blockages.

RADIATION COOLING

RADIATION cooling basically is the only means of dissipating heat in spacecraft. In aircraft and missiles it is not used as the primary means of heat transfer, as we have noted, though it is present to some extent in all designs.

There inevitably is radiation when there is a temperature difference, and it can be very useful in avoiding hot spots, particularly when high-temperature filaments are used. Small holes in a conduction sleeve around a tube, for example, let the heated filaments "see" the cooler surroundings and limit their temperature. The radiant heat exchange between two bodies involves the factors F_e and F_a (*Table VI*) and is expressed by:

$$Q = F_e F_a A \sigma (T_1^4 - T_2^4).$$

Blackening or polishing of component containers can do a great deal to bring down temperatures by improving either the emissivity or the reflectivity (depending on the application). Black wrinkle enamel has a particularly high emissivity (*Table VII*).

When a heat-dissipating element like a transformer is close to a heat-sensitive component, the heat dissipator should be coated with a finish of high thermal emissivity to increase the heat transfer. The heat sensitive element should be shielded by a coating of high reflectivity or by separate shielding. It should also have a direct thermal path to the local heat sink of the assembly, so that it is conductively isolated from the heat source.

Table VII: Thermal Emissivities of Surfaces

	Temperature (Deg F)	ϵ
Polished aluminum	212	0.095
Rough-polished aluminum	212	0.18
Oxidized aluminum	200	0.20
Aluminum paint	212	0.27–0.67
Highly-polished brass	500	0.030
Dull-plate brass	120–660	0.22
Carbon (lampblack, more than 0.003 in. thick)	100–700	0.945
Polished copper	242	0.023
Black wrinkle enamel	170–295	0.01
Glass (pyrex, lead, soda)	500–1000	0.95–0.85
Rough-polished iron	212	0.17
Polished cast iron	392	0.21
Black matte shellac	170–295	0.91
Polished silver	100–700	0.022–0.031
Stainless steel	450	0.52
Polished steel	212	0.066
Oxidized steel	390–1110	0.79
Tin (commercial plated sheet iron)	212	0.075
Tungsten filament	80–6000	0.032–0.035
Polished zinc (commercially pure)	440–620	0.045–0.053
Zinc (galvanized sheet)	212	0.21

COMBINED HEAT TRANSFER

IN ALL COOLING SYSTEMS, the sum of the heat produced by all the internal sources must equal the heat that is dissipated. To put it in terms of electric circuitry, the thermal potential, or temperature difference, corresponds to the electric potential, or voltage, and the thermal resistance corresponds to electric resistance. The sum of the temperature drops in a multi-slab series of thermal resistances, which may include convective films and radiating surfaces, equals the total temperature difference across the entire arrangement of resistances. The thermal resistances for conduction, convection, and radiation are, respectively, L/kA, $1/h_cA_1$, and $1/h_rA$.

DESIGN PROCEDURE

TO EXPLAIN the steps in cooling system design, we will take the case of a forced-convection system (on the assumption that we are dealing with high-heat-dissipating components and areas containing large numbers of heat dissipators). The first step, however, applies for all cooling systems. The heat dissipation can be calculated from the formulas we have given.

• Find out the nature of the heat load. Check the major sources of heat that are particularly likely to create hot spots and determine the approximate distribution of heat (which will vary depending on whether

Radiation from an Earth Satellite

The equilibrium temperature for the shell of an earth satellite is given by an energy balance around the satellite:

$$Q_s + Q_{se} + Q_e + Q_i = Q_r = \sigma F_e F_a A (T_s^4 - T_r^4)$$

$$\begin{aligned} Q_s &= \alpha\pi r^2 E_s = 442\alpha\pi r^2, \\ Q_{se} &= \alpha\pi r^2 E_{se} = 158\alpha\pi r^2, \\ Q_e &= \alpha\pi r^2 E_e = 102\alpha\pi r^2, \end{aligned}$$

where Q_s is direct solar radiation (in btu/hr); Q_{se}, solar radiation reflected from the earth (in btu/hr); Q_e, direct earth radiation (in btu/hr); Q_i, internal heat generation, equaling 3.413P (in btu/hr), where P is the internal electric power (in watts); Q_r, satellite radiation; A, the surface area of the satellite shell, equaling $4\pi r^2$ for a sphere of radius r (in feet); T_s and T_r are the absolute temperatures (in degrees R) of the satellite shell and outer space, respectively (as T_r roughly equals 5.4 deg R, its contribution compared with that of T_s is so small that it can be assumed to equal zero); F equals 1; F_e equals the emissivity (ϵ); E_s, E_{se}, and E_e are the incident radiation per unit area from the various sources; and α is the absorptivity of the satellite's outer surface material at the wavelengths of the incident radiation from the various sources. As these wavelengths are a function of the temperature of the radiator, α is the same for Q_s and Q_{se}. According to Kirchhoff's law, α and ϵ are equal for radiations of identical temperature and wavelength, and ϵ rather than α can therefore be used in describing Q_e so as to avoid confusion in nomenclature. The emissivity of the shell at the shell temperature and the emissivity of the shell connected with terrestrial radiation can be assumed to be equal, because of the relative closeness of the temperatures of earth and satellite. The heat balance therefore is:

$$422\alpha\pi r^2 + 158\alpha\pi r^2 + 102\epsilon\pi r^2 + 3.413\rho = 4\pi r^2\sigma\epsilon T_s^4,$$

which can be solved to derive an expression for the equilibrium temperature of the shell:

$$T_s = 155.3\left(150\frac{\alpha}{\epsilon} + 25.50 + 1.09\frac{P}{\epsilon d^2}\right)^{\frac{1}{4}},$$

where d is the shell diameter (in feet).

T_s, we can see, depends on α/ϵ and ϵ. If no internal heat is generated, it is a function of α/ϵ only. Representative values of α/ϵ are: silicon oxide on polished metal, 0.1; lampblack, 1.0; polished stainless steel, 9.0.

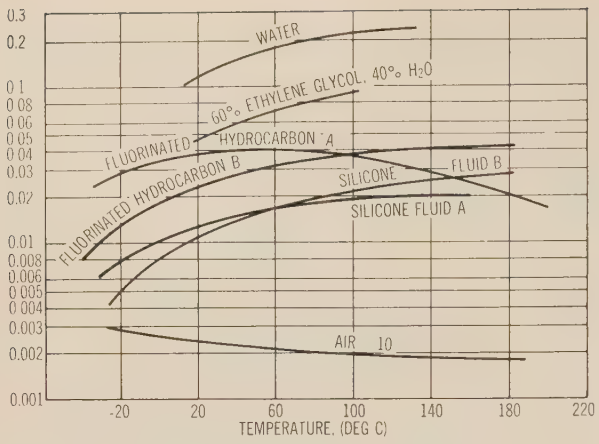


FIGURE 6: Mouromtseff number vs temperature for various coolants, where density is expressed in gm/cm³; conductivity in gm-cal-cm/sec-cm²-deg C; absolute viscosity, in poises; and specific heat, in gm-cal/gm-deg C.

operation is intermittent or continuous). Also determine whether any unusual weight and volume restrictions are imposed on the cooling system, what the maximum surface temperatures and approximate dimensions of the individual components are, and how the components are arranged.

• Select the fluid for the required temperature range that has the highest heat-transfer coefficient as well as all other necessary properties. The Mouromtseff number (N_{Mour}) provides a convenient means for evaluating fluids for forced convection. The heat-transfer coefficient of a coolant fluid is a function of the fluid's density, viscosity, thermal conductivity, and specific heat. For example, the coefficient for forced convection in a duct or confined channel is:

$$h = C\frac{k}{d}\left(\frac{\rho v d}{\mu}\right)^{.8}\left(\frac{c\mu}{k}\right)^{.4}.$$

Ambient Temperature

One of the most widely misused expressions in thermal design is "ambient temperature." In fact it has become so ambiguous a term that in many cases it is meaningless.

Generally, ambient temperature is the "temperature of the surroundings." Often it is used to mean the average temperature of the cooling medium, sometimes the temperature of the coolant in close proximity to a component. It may also refer to the temperature of the atmospheric region surrounding a vehicle. Even when it is understood that "ambient" refers to the temperature surrounding a component, it is not precisely clear which temperature is meant.

Therefore, when you specify the operating conditions for an electronic component, note the temperatures of the conduction sink, radiating walls, and cooling medium. When you design a cooling system, determine very carefully exactly what is meant by the component manufacturer's operating "ambient"—if necessary, find out in detail about the manufacturer's testing methods.

N_{Mour} is derived by retaining only the terms referring to fluid properties:

$$N_{Mour} = \rho^{0.8}k^{0.6}c^{0.4}/\mu^{0.4}.$$

When fluids are compared for a given channel and a given flow velocity, N_{Mour} is proportional to the forced-convection coefficient (*Fig. 6*).

• Calculate the heat load (Q.).

• Select a reasonable coolant flow path as a basis for your heat-transfer calculations.

• Select a coolant mass flow rate (W.).

• Calculate the coolant temperature rise (Δt) from:

$$Q = Wc\Delta t.$$

• From the allowable component temperature and the coolant temperature, compute the maximum allowable temperature difference between the cooled surface in question and the coolant.

• Calculate the appropriate heat-transfer co-efficients.

• Calculate the convection heat transfer area.

• Calculate the heat that is actually transferred by substituting:

$$Q = h_c A \Delta t,$$

where Δt is the temperature differential between component surface and bulk coolant.

• Compare the amount of heat internally generated with the amount of heat dissipated by convection. As we have noted, the dissipated heat must equal to or exceed the heat that is generated.

• If the dissipated heat is less than the heat that is generated, increase the flow rate, thus increasing the heat-transfer coefficient, and/or increase the surface area. Extended surfaces can be useful in increasing both free- and forced-convection heat transfer.

• If the dissipated heat is acceptable, check the pressure drops throughout the system to see whether the required pump size is acceptable. If the pressure drop is not acceptable, changes must be made in such parameters as the flow passage dimensions. The iteration generally converges rapidly and the pressure and heat-transfer requirements eventually are met simultaneously.

Every new electronic system and every old one operating in new environments raises thermal problems that never precisely duplicate any previous situation. Furthermore, correlations of heat-transfer parameters generally are based on lab idealizations of specific, isolated cases and relate only approximately to the realities of application. Performance therefore must be the real test of a thermal design. Usually it is not necessary to make an evaluation of completed hardware for trial-and-error design (which would be costly and time-consuming), since acceptable data can, as a rule, be taken from instrumented thermal mockups of the electric design.

Finally, perhaps the soundest bit of advice: *Start the thermal design during the very early stages of electric design.*

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Shock and Vibration Design

by H. C. Lawrence,
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DYNAMIC ENVIRONMENTS

SHOCK AND VIBRATION start to be problems long before electronic equipment is actually installed in the vehicle—the designer must always take handling and transportation factors into account if he wants to get factory-to-field dependability. His main concern, though, will be the mechanical shock and sinusoidal, random, and transient vibrations of the vehicle environment (*Fig. 1*).

- *Commercial aircraft* generate vibrations in the 2-400 cps range, whether powered by piston engines or jets. Accelerations range as high as 20 g for piston planes and as high as 30 g for jets. While landing or taxiing, extreme values go up to 15 in. double amplitude in the 2-3 cps range.
- *Helicopters* have accelerations of up to 10 g in the 2-300-cps range. From one to 15 cps, excursions are particularly large, primarily because of the presence of the rotor. Landing shocks of up to nine g must be allowed for in the case of military designs.
- *Multi-engine military jets* in subsonic flight produce an environment similar to the commercial jets', but in supersonic flight there are 10-g accelerations from five to 2000 cps, with excursions up to 0.1 in. from five to ten cps. Weapon-firing causes localized transient vibrations of 50-75 g at up to 100 cps. There are also random vibrations of more than one g^2/cps up to 500 cps.
- *Jet fighters* have serious sinusoidal disturbances up to 2000 cps. Excursions range from 0.175 in. at five cps to 0.01 in. at 100 cps.
- *Carrier aircraft* also can have landing shocks of up to nine g.
- *Missile* vibrations at launch have peaks of 400 g at high frequencies and sustained sinusoidal magnitudes of 10 g. Near the engine compartment, 10 g^2/cps of random vibrations has been recorded in the 200-700-cps range, with sustained vibrations as high as 3.5 g^2/cps. In the payload, guidance, and control compartments, 0.2 g^2/cps is a more likely peak.

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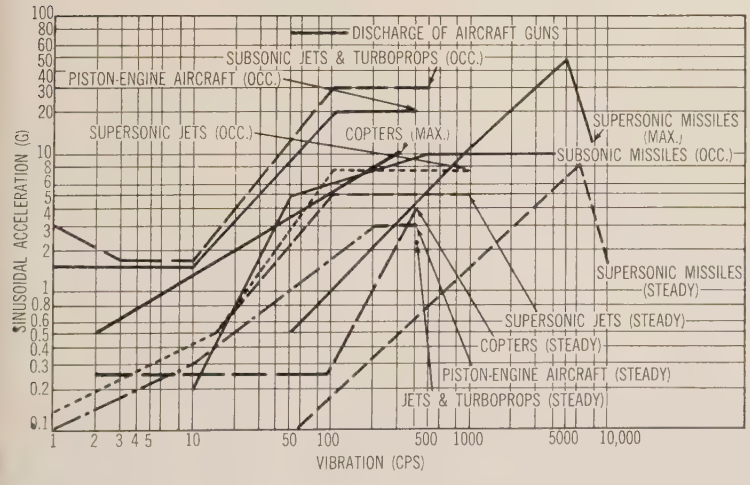

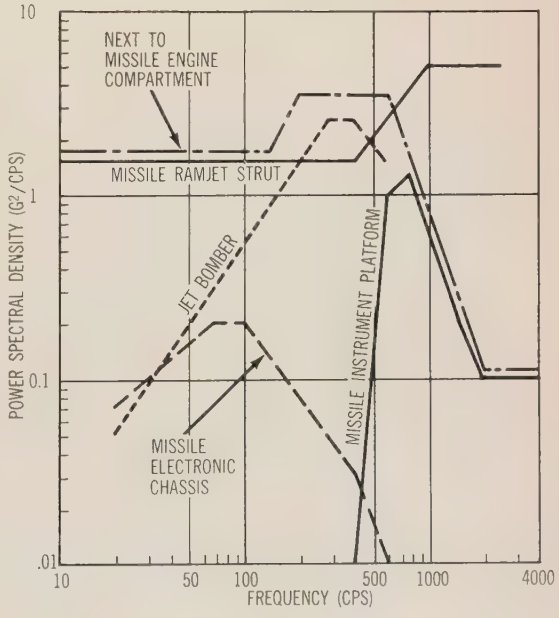

FIGURE 1: Sinusoidal vibrations of aerospace vehicles (top) and peak random data for missile flights, during which the greatest disturbances occured at liftoff, Mach 1, and stage separation (right).

Table I: Mil Specs for Shock and Vibration

Mil-C-172C	DOD	12/8/58	Cases Bases, Vibration Mounts for Electronic Equipment in Aircraft
Mil-S-4456	USAF	3/12/53	Method and Apparatus for Shock, Variable Duration
Mil-T-4807	USAF	7/8/54	Tests: Vibration and Shock, Ground Electronic Equipment
Mil-E-4970	USAF	6/1/55	General Specification for Environmental Testing, Ground Support Equipment
Mil-E-5272C	ASG	1/20/60	General Specification for Environmental Testing, Aeronautical and Associated Equipmen
Mil-E-5400D	ASG	5/16/60	General Specification for Electronic Equipment, Aircraft
Mil-T-5422E	ASG	4/13/59	Testing, Environmental, Aircraft Electronic Equipment
Mil-P-9024B	USAF	5/2/55	Specifications and General Design Requirements for Packaging: Guided Missile Weapon Systems
Mil-G-9412	USAF	11/8/57	Engineering and Procurement Data for Ground Support Equipment for Weapons Systems Support Systems, Sub-systems and Equipment.

Shock and Vibration Definitions and Formulas

Periodic Vibration: Any vibration with a repetitive waveform per time interval. Its most common form is sinusoidal vibration.

Random Vibrations: Vibrations covering the simultaneous existence of any and all frequencies and amplitudes in any and all phase relationships. Generated, for example, in missiles by the interaction of many variables such as velocity, load thrust, atmospheric density, structure. Usually confined to statistical analysis. Also called white noise.

Shock: A transient, or impulsive, application of acceleration (not periodic). Velocity shock is a sudden change in velocity, as at drop termination or a similar impact. Impulse shock is the sudden change in velocity from rest, as when the hammer strikes the test platen on a shock test machine.

Degrees of Freedom: Fundamentally six for a free body. Rotationally they are pitch, roll, and yaw; translationally they are vertical, lateral, and longitudinal.

Acceleration: 32.2 ft/sec/sec in gravitational units, or g. The dimensionless "G" represents the acceleration applied to an object divided by g.

Resonance, or Natural Frequency: The frequency at which an element reacts most vigorously to an applied vibration.

Acceleration Density, or Spectral Density, Power Density, etc.: Random-vibration term. A measure of vibration intensity, it is the mean square of the acceleration amplitude per unit bandpass width. Usually expressed in g^2/cps, sometimes in g RMS.

Mechanical Impedance: Ratio of force to velocity during sinusoidal vibration. Usually a factor in structural rather than isolator analysis.

Damping: A force tending to resist vibration. Viscous damping exerts a force proportional to the applied velocity (as in hydraulic shock absorbers). Coulomb or friction damping has a constant force. Isolators use damping techniques not directly analogous to either of these, but rather more proportional to displacement.

Hysteresis: The energy loop on a load-deflection curve for a friction- or displacement-damped system. It is the component of displacement not returning to zero by virtue of frictional resistance.

Coupling: The condition resulting from the vibration of an isolated system whose CG is displaced from the isolator plane by a moment arm (couple). Causes rocking vibratory response. A system whose CG coincides with the plane of the isolators and is equidistant from these is said to be decoupled and vibrates without rocking (i.e., translationally).

Isolator (also shock mount, a misnomer): Used to reduce the transmission of vibratory accelerations to sensitive equipments.

Spectrum: In vibrations, a range or bandwidth of frequencies.

Octave: The span between two frequencies whose numerical ratio is 2.

A — single amplitude (in., base to peak, sinusoidally)

B — vibration bandwidth (cps, usually random vibration)

cps — cycles per second (vibratory)

DA — double amplitude or excursion (in., peak to peak)

db — decibel, or ten times the log of the ratio of two transmissibilities:

$$db = 10 \log_{10} \frac{T_2}{T_1}$$

f — vibration frequency, or resonance (cps, usually a disturbance)

f_N — natural frequency, or resonance (cps, often an isolator):

$$f_N = \frac{1}{2\pi} \sqrt{\frac{Kg}{W}} = \frac{3.13}{\sqrt{\delta}}$$

G — acceleration (dimensionless):

$$G = 0.102 f^2 A$$

G_o — power spectral density (g^2/cps)

G_R — RMS acceleration:

$$G_R = \sqrt{BG_o}$$

G_{RT} — total RMS acceleration:

$$G_{RT} = \sqrt{G_R^2 + (0.707 G_S)^2}$$

G_S — sinusoidal acceleration

g — gravitational acceleration (386 in./sec²)

I_E — isolation efficiency (zero at T = 1, negative for T>1, positive for T<1):

$$I_E = \frac{A_{in} - A_{out}}{A_{in}} \times 100\%$$

K — spring rate (lb/in.)

T, Q — transmissibility, or ratio of output to input

$$T = Q = \frac{A_{out}}{A_{in}} = \frac{G_{in}}{G_{out}} = \frac{1}{1 - (f/f_N)^2}$$

W — mass weight (lb)

δ — static deflection (in.)

• *Spacecraft* can be considered a special case of missile design and subject to the same dynamic environment as missiles. Until detached, they vibrate at modest levels, since they are remote from the engine. There are random vibrations from wind loadings and air impingement, and deceleration loads during atmospheric re-entry.

Dynamic tolerances should be based on actual flight data, since the variations in dynamics between similar vehicles can be very large.

In most cases, electronic equipment that must be protected against shock and vibration is designed to a spec. Military specs usually are based on reasonably good empirical data and provide for straightforward tests for dynamic qualification for the equipment (*Table I*). The designer's worst problem is the spec based on a military spec but altered to fit a requirement determined by a contractor. Often this "requirement" is the product of likely-looking data and a factor of two.

FRAGILITY

THE FRAGILITY of a system probably is best determined by analyzing the fragility of the components and other elements that make up the system (*Fig. 2*). In electronic gear, vibration failures are four times as frequent as shock failures. Many components and systems can take up to 75 g of shock but cannot perform under as little as two g of sustained vibration.

Vibration causes structural elements to build up to resonance, and fatigue failure is brought on quickly by the continuous energy input and overstressing. Transient shock may cause large motions of structural elements, but these rapidly diminish, since no additional energy is being applied.

Electronic chassis almost always fail under vibrations of five g up to 2000 cps. They usually tolerate shocks of 50 g for six milliseconds without failure, although often with physical distortion.

The most frequent vibration failures are due to flexure of *electric leads* supporting resistors or capacitors and to *vacuum tubes* that loosen, fall out of sockets, or short. Vacuum tubes usually can take about three g up to 2000 cps; special types can take more than 10 g.

• *Relays* chatter and ultimately fail when subjected to 10-15-g vibration at more than 500 cps. Special relays can take up to 100 g. Plunger and rotary types are most rugged; clapper types are relatively fragile.

• *Transistors, capacitors, and resistors* have low mass and good rigidity. Correctly supported and anchored, they withstand as much as 15 g sinusoidal. Capacitors and resistors in particular usually fail from lead flexure rather than structural breakdown.

• *Terminals, switches, transformers, and circuit-breakers* are generally rugged and stand up in severe dynamic environments. Shock and vibration failures often are the fault of poor bracket and hold-down design rather than of the element itself.

• *Electric cables and connectors* also need to be well anchored. Care must be taken to prevent flexure, abrasion, and noise voltage due to flexing high-impedance coaxial leads.

Actual fragility data, of course, are the best basis for rugged design. Component manufacturers should be asked to recommend dynamic tolerances for their products before general values such as we have given are used.

In direct conversation with designers, many manufacturers rate their products extremely conservatively (written data are rarely provided). Several units for which a maximum shock resistance of only five g is claimed actually have withstood 30-50 g without malfunction or failure. Whenever possible, therefore, the system designer should run dynamic tests on components and chassis.

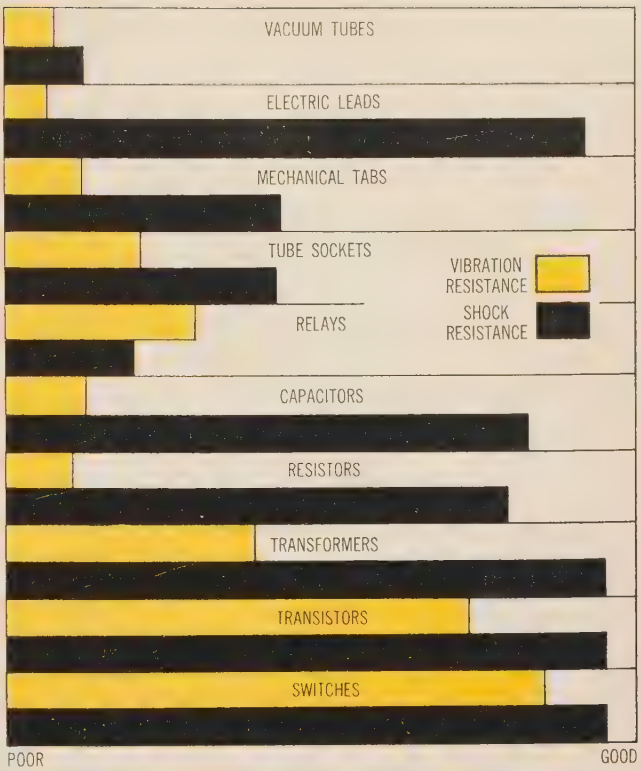

FIGURE 2: Relative dynamic resistances of common components.

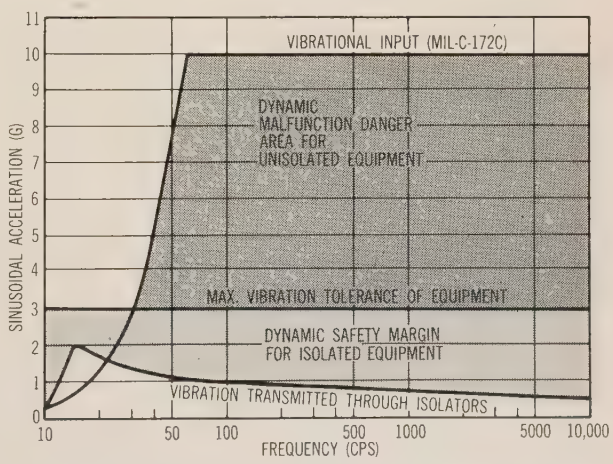

FIGURE 3: Dynamic safety margin for isolated equipment with a three-g vibrational tolerance for a typical Mil-spec input.

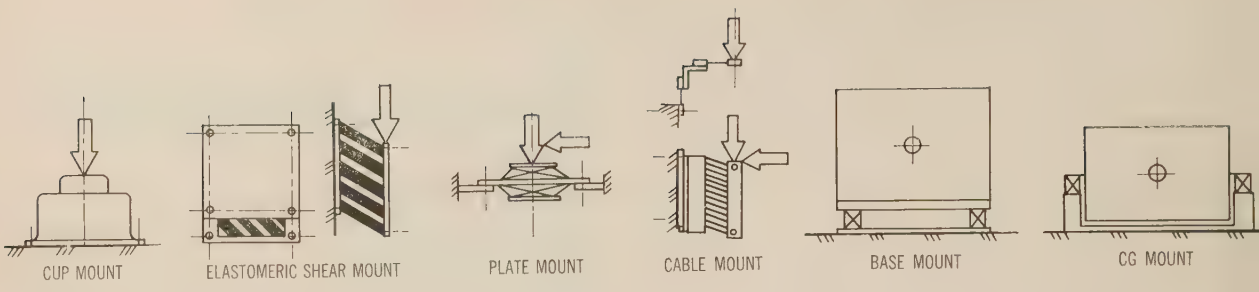

FIGURE 4: Common isolators. Arrows show load-application lines for best performance.

SYSTEM DESIGN

IN THE INTERESTS of sound dynamic design, avoid cantilevers and sliding joints and use stiff brackets and, where appropriate, damped structures (*Table II*). Try to get high stiffness-to-mass ratios. Anchor large masses, such as transformers, firmly to stiff structures, and keep masses off panels.

Either rugged design, tuned to tolerate vibration, or a conventional design using shock or vibration isolators can provide dynamic resistance. Ruggedized units are sturdy, reliable, and self-contained. Their disadvantages include increased development time and cost and often excessive weight. They also require special components and extensive dynamic proof-testing, and some components (e.g., electron tubes) are inherently unsuitable for extreme ruggedizing techniques.

Supplementary isolators for conventional chassis are cheap, simple, and quick to install. Made of standard elements, they provide a margin of protection well beyond most requirements (*Fig. 3*). However, they take up space and create logistic problems.

Two basic kinds of isolator are available:

- elastomers, including natural and synthetic rubbers;
- metals, including springs, metal meshes, and wire-rope and cable types.

Elastomers generally are used in shear or designed to diaphragm, buckle, or otherwise overcome relatively stiff compression characteristics. Several synthetics offer good damping.

Among *metallic* isolators, springs lack damping, but mesh and cable provide smooth friction damping—as a function of motion—that provides low transmissibility at resonance and good isolation above resonance.

Pure friction-damped isolators should be avoided—they are erratic and tend to stick or chatter during high-frequency vibration. *Viscous dampers* of the automotive shock-absorber type are velocity-sensitive and tend to lock out under high-frequency vibration.

In the absence of temperature extremes, rubber isolators may be perfectly adequate. Moderate temperatures may demand synthetics, and wide temperature ranges require metal mounts.

For satellite equipment isolators, the effects of nuclear radiation must be considered. Here, too, metal mounts may be preferred because of their minimal outgassing properties. In high-altitude aircraft, ozone adversely affects rubber isolators. At times, the petroleum products, solvents, and exotic fuels can be an important factor. In some cases, a metal mount's self-grounding properties may simplify an installation.

Isolators most often are small, resiliently supported cups with a projecting tapped stud, and four attachment holes. This rudimentary type is defined by military spec and suitable for solving simple dynamic problems. Other forms include diaphragms, springs and resilient cushions, springs with plastic dampers, and cable assemblies (*Fig. 4*). They may be either cuplike or large, complex structures adapted to a particular chassis, system, or vehicle.

The isolator manufacturer should be consulted on tolerable overload, best attitude, performance variation under acceleration overload, and tolerance to vibratory input. A few isolators—not the cup type—can take heavy overloads without bottoming and can attenuate shock inputs. In general, cup-type isolators do not perform well when inverted, nor can they tolerate large-excursion vibratory inputs (on the order of 0.125 in.) at resonance.*

Isolators perform best when they are worked into the design right at the start and are literally "built in." This is the easiest way of getting all-attitude performance while saving space and weight, and provides the advantage of CG mounting with decoupled rocking modes (*Fig. 5*). A package resiliently supported at its base resonates in two rocking modes under lateral vibration, because the

* Most Mil-spec isolators are designed to accept only 0.60 in. of input excursion. At resonance with $T = 5$, this would mean a response excursion of five times 0.06 in., or 0.3 in. Very few isolators can take an 0.08 in. input excursion at resonance.

Table II: Mechanical Design for Maximum Dynamic Resistance

Use	Avoid
Minimum spans	Cantilever elements
Short load paths	Sliding joints
High stiffness-to-mass ratios	Notches, corners, cracks, points, and other stress raisers
Box, Z, and channel sections for structural elements	High static stresses
Stress relief in sheet-metal parts	Mass concentration
Positive-locking and -fastening devices	Attachment of masses to panels
Counterbalancing on pivoting masses and links	Cantilevered masses in close proximity
Good clamp support for leads	Undersized fasteners
Advantageous dynamic orientation of masses	Flimsy tabs, brackets, and feet
Potting for small electric parts	Frequency responses in the dynamic spectrum

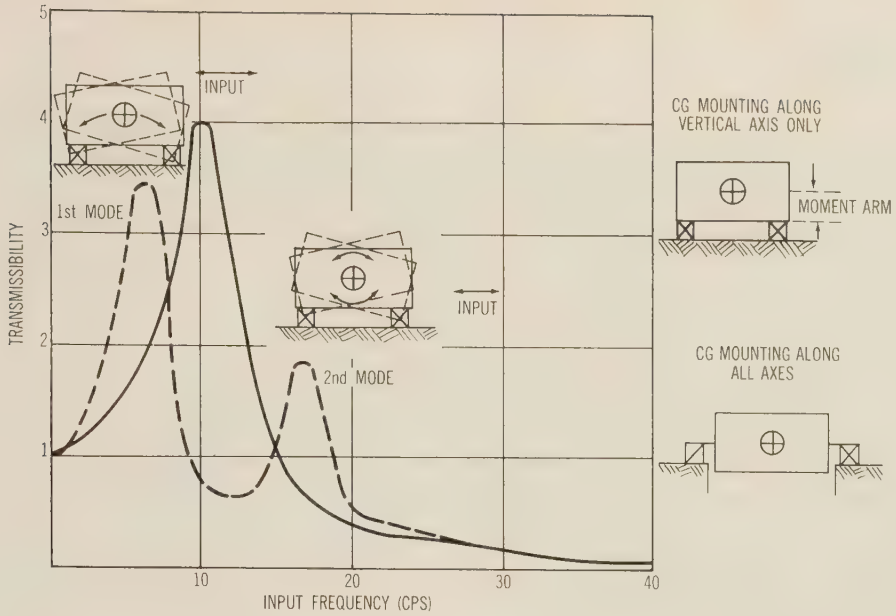

FIGURE 5: CG mounting and base-type mounting for a 10-cps NF isolation system. The solid curve shows the response to vertical and lateral inputs for the CG mounting and the response to vertical inputs only for the base mounting; the dashed curve shows the response to lateral inputs for the base mounting. Because of the moment arm of the CG above the isolators, the last response produces two distinct resonances, neither of them translational. Both these "rocking" modes are due to the coupling effect of the eccentric CG (which in this case is vertically eccentric but horizontally centered). The first rocking mode is below the translational natural frequency as the package rocks about an imaginary point several inches below the isolators; the second is above the translational natural frequency as the package rocks about its own CG. A CG mounting decouples, or eliminates, the rocking moment arm, and all responses become translational. Rocking modes cause large motions and are especially harmful to gyros.

CG is coupled by its moment arm above the plane of the isolators. The two resonances greatly extend the spectrum of frequencies over which the mounted package is not protected from vibration. The rocking also exaggerates lateral motion, which requires excessive sway space if collisions with nearby equipment are to be avoided.

Whether to shock-mount the complete system, a chassis, or elements within the chassis is the designer's final major problem. System mounting may be desirable where cabling, connectors, pneumatic lines and cooling source can be more simply built into an isolation rack. If a particular chassis lacks ruggedness, it should be separately isolated. In a system that as a whole is quite resistant to shock and vibration, it may be worth while to isolate some relatively fragile component like a crystal oven or gyro.

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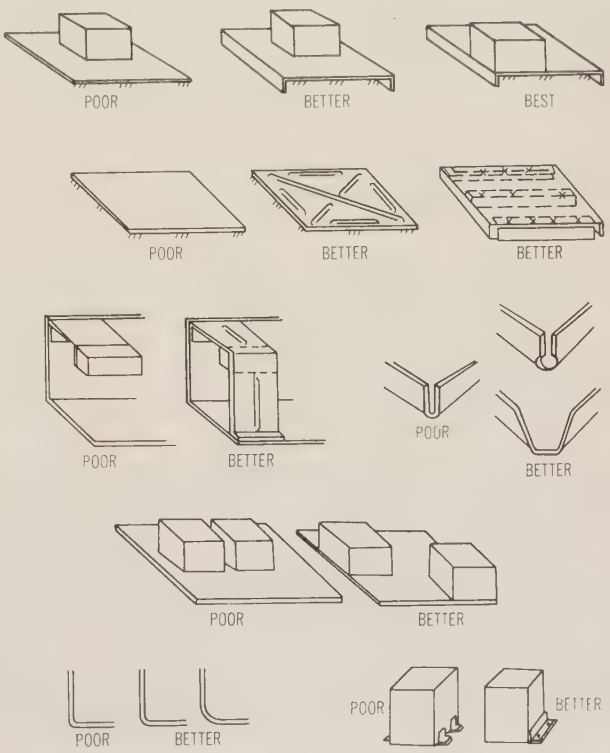

MECHANICAL design requirements for good dynamic system tolerance.

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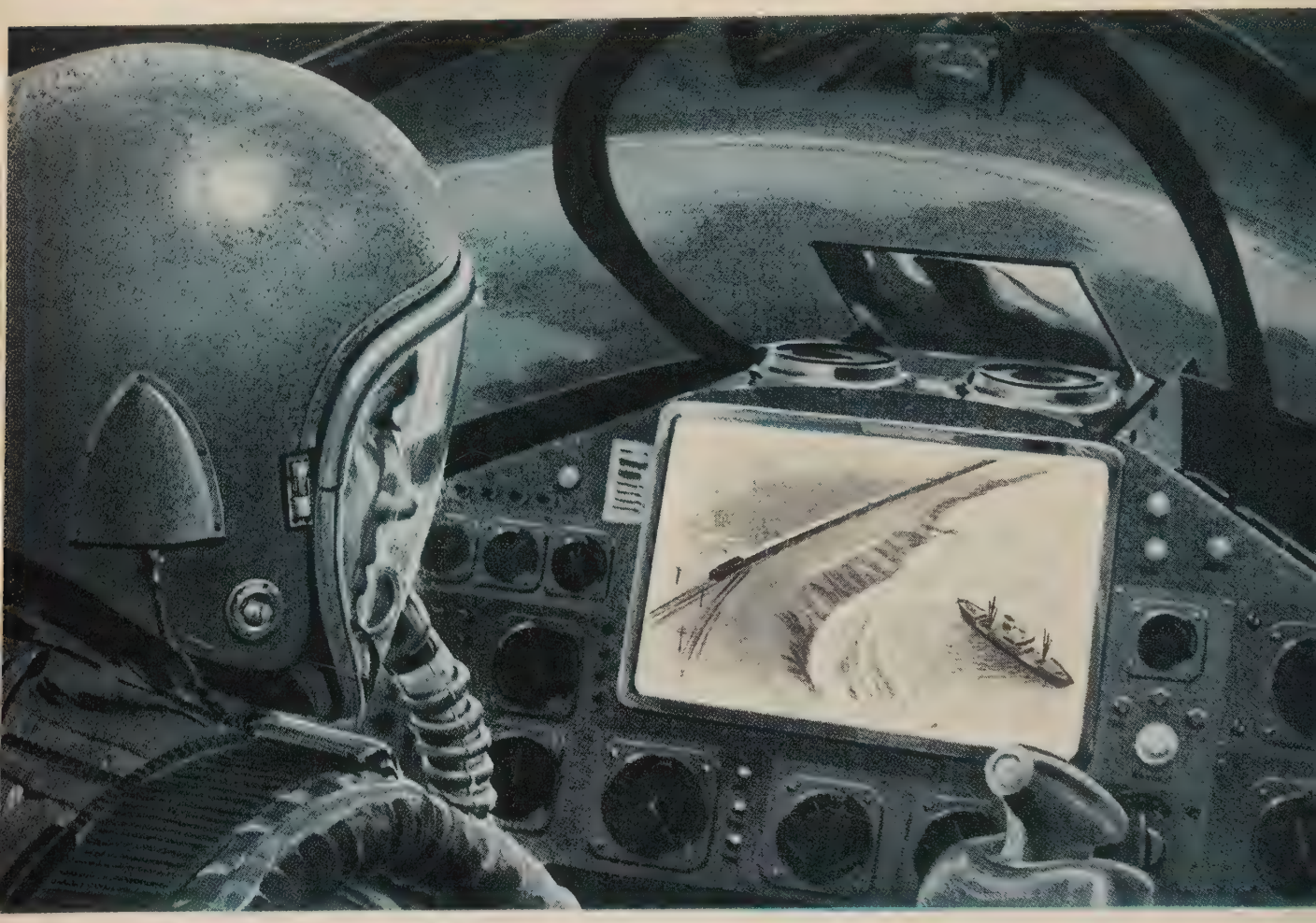

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GENERAL ELECTRIC

Light Military Electronics Department

Utica, New York

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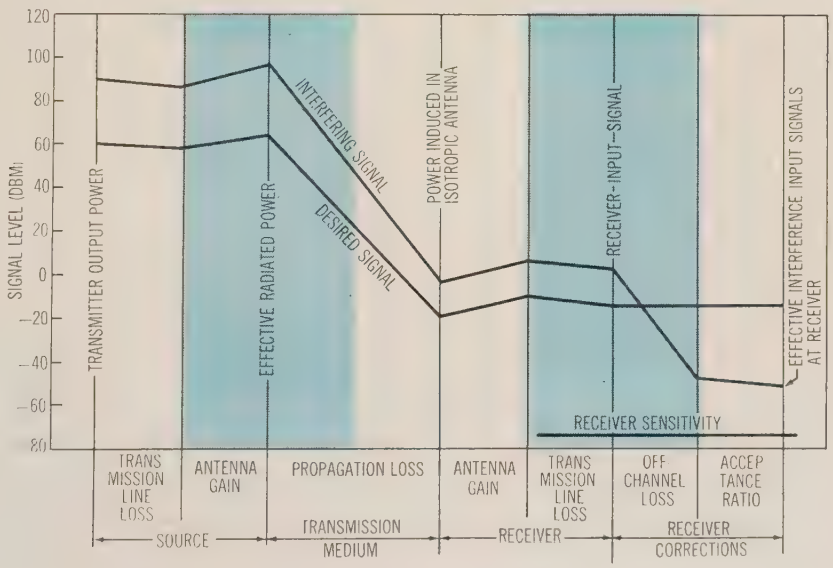
Designing for Electromagnetic Compatibility

by Samuel Burruano, *Consultant, Burruano Associates, Inc.**

Electromagnetic compatibility. The ability of electronic equipment to operate as designed in its internal and external electromagnetic environments without serious loss in performance and without, through the electromagnetic energy it generates, causing other equipment to malfunction.

* Burruano Associates, Inc., 51 Sullivan St., Westwood, N.J.

THE ELECTROMAGNETIC compatibility of the electronic equipment in aerospace vehicles depends on external and internal factors. Externally, there is the complex electromagnetic environment created by RF transmitters on the ground and in other aerospace vehicles and by natural emissions from the atmosphere and celestial bodies through which the vehicle must fly, as



PLOT OF DATA from an interference prediction work sheet for a transmitter-receiver pair.

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well as the radiated and conducted interference due to system elements external to the vehicle—launch complex, ground checkout equipment, telemetry equipment, tracking equipment, etc.

Internally, the designer must consider interactions among circuits within a black box. This problem is particularly troublesome in military aircraft, missiles, and space probes. These vehicles have little room for the many electronic boxes that they must carry. So what you get is high-density installations with a maze of field couplings. System elements often share common power supplies and antennas and have many common interfaces for control and information transfer.

Little can be done by the systems designer to change

Specifications

Military procurement regulations require that equipment and systems comply with an interference spec. The three specs in the Table give RFI design goals and methods of RFI control for aircraft and missile systems that provide a 90-95 per cent probability of compatibility. Other interference standards' include Mil-Std-449, which outlines spectrum-signature measurement techniques, and Mil-I-6051-C, which covers general weapon-system compatibility.

The specs in the table do not cover the subsystem interfaces related to cable selection, use, and routing, nor the general grounding problem. They require various limits and measurement methods and in some cases differ even in the measuring equipment they prescribe and in the type of antenna to be used with it.

It is important to maintain close contact with interference personnel in military agencies—in many cases this is a spec requirement. Mil-I-6181D, for example, requires not only an interference-control plan detailing the design techniques to be used in meeting the spec but also a test plan showing how spec test procedures will be used.

Offices in charge of ballistic-missile programs often write their own interference specs. GM-07-59-2617A for the Minuteman, for instance, is similar to Mil-I-6181D but includes additional requirements like transient tests, specific grounding procedures, and measurements down to 30 cycles. Great care must be taken in following the single-point grounding requirement—it doesn't take into account the RF problem and could add weight by making filters necessary on neutral leads and cause RF radiation and pick-up problems from neutral, signal, and control returns.

	Mil-I-6181D (USAF)	Mil-I-16910A (Bu Ships)	Mil-I-11748B (Signal Corps)
Conducted measurement			
Frequency range	0.15-25 mc	0.15-100 mc	0.15-30 mc
Method	stabilization network & current probe	stabilization network & current probe	stabilization network
Radiated measurement			
Frequency range	0.15-10,000 mc	0.014-1000 mc	0.014-36,000 mc
Antenna distance	1, 3 or 25 ft, depending on equipment class & frequency range	3-5 ft, depending on equipment type	3-100 ft, depending on class
Antenna conducted			
Frequency range	0.15-10,000 mc	0.15-1000 mc	0.014-36,000 mc
Receiver limits	broad band: 60 db above 1 uv per mc; CW: 40 db above 1 uv	400 uuw	400 uuw
Transmitter limits	up to 3rd harmonic: 60 db down; above 3rd harmonic: 80 db down	50 db down	60 db down or 10^{-8} W but less than 1 W (harm.); 80 db down or 10^{-8} W but less than 10^{-2} W (non-harm.)
RF Susceptibility			
Frequency range	0.15-10,000 mc	no requirement	0.15-30 mc conducted, 0.014-36,000 mc radiated
Conducted limits	100,000 uv		CW: 100,000 uv; broad band: 90 db above 1 uv per mc
Radiated limits	100,000 uv		0.1 v/m
AF Conduction			
Frequency range	50-15,000 cps	no requirement	no requirement
Limits	3 V		
Front-End Rejection			
Frequency range	0.15-10,000 mc	no requirement	0.014-36,000 mc
Spurious limits	60 db in band, 80 db outside band		CW: 60 db; broad band: 30 db
Image	60 db		
Intermodulation	two-signal test, no detectable response		no requirement

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Table I: RFI Sources

Broad Band	Continuous-Wave
Radar transmitters Trigger pulses (synchronizer) Thyratrons & gas tubes (servo control, switching) Sweep circuits Video pulses Modulator (pulse generation for transmitter) Transmitter spurious (harmonics)	Receivers Frequency synthesizers Local oscillators Spurious oscillations
Computers (logic circuits, switching)	Servo amplifiers (parasitic oscillations)
DC motors (commutation)	Transmitters Multiplier circuits Spurious outputs (harmonics, sub-harmonics)
AC motors (DC excitation)	Timing oscillators
Solid-state power supplies (diode rectifiers)	Computer clocks
Switching circuits Relay contacts Thermostats Rotary & snap switches	Reference generators
Fluorescent lights (aircraft installation)	

the external electromagnetic environment through which his vehicle must pass. Interference from this environment is via direct or indirect antenna-to-antenna path. What he can do is to analyze this signal environment and predict its effect on his equipment, so that he can eliminate or minimize degradations caused by radio-frequency interference (RFI). The analysis must take into account the geographical location of the interference sources, the times when they will be on the air, frequency assignments, transmitter powers, antenna gains and orientations, path losses, signal modulations, spurious emissions, and the sensitivities of receivers over their passbands.

The designer plays a much more active role when it comes to controlling the compatibility of the parts of an electronic system—both internal and external to the vehicle. Again analysis and prediction are important (and are applied much as in the case of the operational environment). What makes the big difference is that, once he has spotted an interfering energy source, the designer can modify it to eliminate or minimize its harmful interaction with other parts of the system.

COMPATIBILITY DESIGN

THE DESIGN of electromagnetically compatible systems requires a detailed analysis of the components

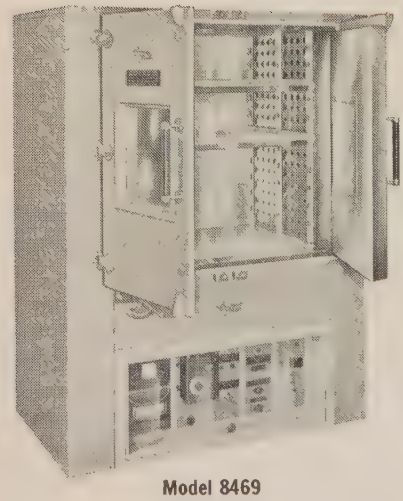
Table II: Receiver Interference Characteristics

Cause	Effect
Inadequate preselection, inadequate shielding, decoupling of local-oscillator stages	local-oscillator radiation
Transmitter characteristics*	intermodulation
Inadequate selectivity, proximity of transmitter & receiver, inadequate frequency spacing	cross-modulation
Inadequate preselectivity & IF selectivity, inadequate frequency selectivity for given channel spacing	adjacent channel
Inadequate preselectivity	image
Inadequate shielding, inadequate IF selectivity between RF & IF stages	intermediate frequency
Grid current flow in RF and/or converter produced by strong, undesired signal, reducing sensitivity by increasing bias	desensitization or blocking
Inadequate shielding of housing, meter face, control, etc.	case radiation

*Determine whether transmitter produces third- or fifth- order products in band. Change frequency of one transmitter to reduce interference.

Launching U.S. Air Force Mace missile, courtesy of the Martin Company, Baltimore, Md.

A BRAIN WARMER FOR THE MARTIN MACE



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*Mil-E-005272B (USAF) Procedure I, Paragraph 4.1.1, Procedure II, Paragraph 4.2.2 and MIL-P-116D, Paragraph 4.4.6.

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in terms of their interference susceptibility and as interference sources. The steps in this analysis are:

- Identify the potential interference sources.
- Identify the sensitive equipment.
- Determine electromagnetic equipment circuit signatures—impedance, signal levels, signal types.
- Categorize the connecting cables (e.g., high-level signal, low-level signal, digital, control, and power).
- Determine the shielding requirements for each black box.
- Determine the isolation requirements in terms of space, shielding, cable selection (twisted pair, shielded, coaxial, etc.) and cable routing (by category).
- Decide on the grounding (multi- or single-point) to be used to get a common low-impedance reference plane.
- Choose the internal equipment suppression techniques and devices (circuit decoupling, circuit isolation, and filtering).

Equipment requirements

RF Sources (Table I)—RFI typically exits from equipment via antennas, case radiation (if there is any discontinuity), cable conduction (and re-radiation), and poor grounding.

Sensitive Equipment—Typical interference-sensitive equipment includes all receivers (*Table II*), autopilot circuitry, computers, squibs, transponders, and infrared circuits. Autopilots are inherently sensitive to line transients; computers, to line transients and case penetration by high-power radar energy; squib ignitions, to high RF currents; and IR circuits to low-frequency signals. Cable induction, case penetration, and common power sources are among the means of transfer.

IR systems in particular are sensitive to RFI—detector elements are susceptible to high peak power-radiation, and preamps are highly susceptible to low-impedance fields.

Cable Signature—Cable parameters and signal description determine the cable signature. Like signatures can be grouped for cable routing to avoid degradation as a result of cross-talk. Cables carrying high-level pulses, for example, obviously should not be routed with low-signal level cables, nor should power circuits be put in the same plug or cable bundle with circuits carrying low-level IR data.

Metal is most important factor

Shielding—Poor seam construction, air vents, meter faces, fuses, shaft openings, etc., create equipment discontinuities through which interference energy can pass. Proper use of seam gasketing, conductive glass, and grounding can reduce the problem, but the metal of the enclosure itself is the most important factor.

Metal shielding cuts interference considerably. If you want to make the best use of it, you must consider what type of metal would be best, the thickness of the metal, the best types of openings, and reflection and absorption losses. RFI can leak through seams, holes, and other openings, and can penetrate thin walls.

Reflection and absorption losses depend on frequency, resistivity, and permeability (*Fig. 1*). Copper, aluminum, and magnesium have proved best for high-frequency shields; iron makes the best low-frequency shield.

The sum (in decibels) of the reflection and absorption losses at a given frequency gives the total shielding efficiency. At 100 kc, for example, a 10-mil-thick copper sheet has a reflection loss of about 70 db and an absorption loss of 10 db, giving a shielding efficiency of about 80 db. An iron sheet of the same thickness has, at the same frequency, an absorption loss of about 120 db and a reflection loss of about 20 db, or a total loss of 140 db.

Leakage through holes in shielded enclosures for ventilation and control adjustment can be reduced by designing the openings as waveguide attenuators and attaching a collar (*Fig. 2*). Collar shielding can also be used for honeycomb ventilation openings. These offer much less resistance to air flow than does conventional screening.

Some general rules for shielding design are:

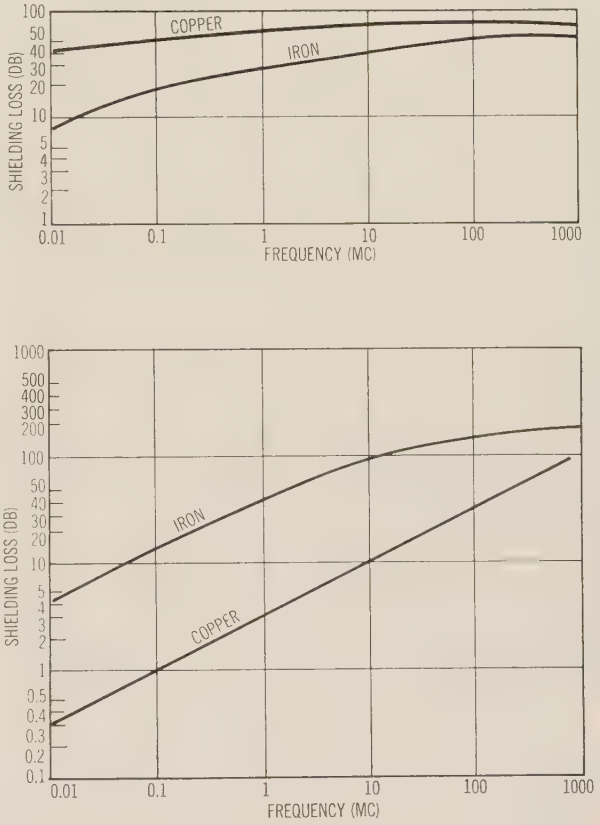

FIGURE 1: Attenuation losses for copper and iron shielding (top) and reflection losses for one-mil-thicknesses (bottom).

- Solder, weld, or rivet all joints.
- Use screen or honeycomb for ventilation openings.
- Use spring fingers or conducting gaskets on lids and panels.
- Keep mating surfaces free of paint and anodized finishes.
- Shield or filter all external leads.
- Install conducting gasket washers under connectors.

Equipment and Circuit Isolation—Where equipment should be physically located for maximum electromag-

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netic compatibility is a matter of interference prediction and good engineering judgment. In an aircraft, for instance, it's not a good idea to put a radar modulator next to a sensitive communications receiver, or a solid-state power supply near an ADF antenna.* Unit placement is always a compromise between functional relationship and the separation needed for RFI isolation.

Equipment interconnection is an interface that causes many problems, partly because it is most often considered to be of secondary importance only. Interconnecting cables can transfer interference from one circuit to another by radiation, induction, or direct connection. To get isolation between cables, you must consider the types and functions of the cable (power, control, signal), the signal sources (transmitters, receivers, computers), and the other electromagnetic parameters that describe the cable circuit's signature. The amount of isolation depends on how the cables are routed, their separation and class, their shielding effectiveness, and sometimes on brute-force means like filters.

The types of cable, in order of increasing shielding effectiveness, are:

- unshielded wire (for non-critical power and control applications);
- twisted pair (for audio frequency circuits);
- shielded wire (for critical power and control applications);
- twisted shielded pair (for audio- and video-frequency multi-point grounding);
- coaxial line (for video and radio frequencies).

Grounding and Bonding—A ground plane that extends throughout the installation is the most fundamental requirement of system grounding. Because of their integrated internal and external metallic construction, missile and aircraft structures provide surfaces of low potential difference to which equipment may be bonded to reduce RFI and cable cross-talk.

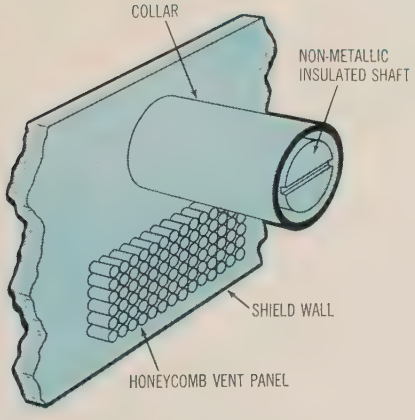
Good rules for bonding are:

- Bond missile and aircraft equipment housings directly to the ground plane.
- Make sure that mating surfaces are clean and free from paint and non-conductive finishes. The bonds should be metal-to-metal.
- Use Iridite or Alodine finishes for corrosion protection and good electric conductivity. Alternatively, use at least two solid, flexible straps with a length-width ratio of 5 or less (*Fig. 3*).

The bonding requirements of Mil-B-5087A (USAF) are an excellent guide.

When you decide between single- and multi-point grounding, you'll find that you've got into a controversial area. The proponents of single-point grounding argue

* Solid-state static inverters, converters (DC-DC and AC-AC), and rectifiers produce RFI voltages many times higher than those of the rotary and vacuum-tube equipment formerly used. In many cases, the conducted RFI level is over a volt.



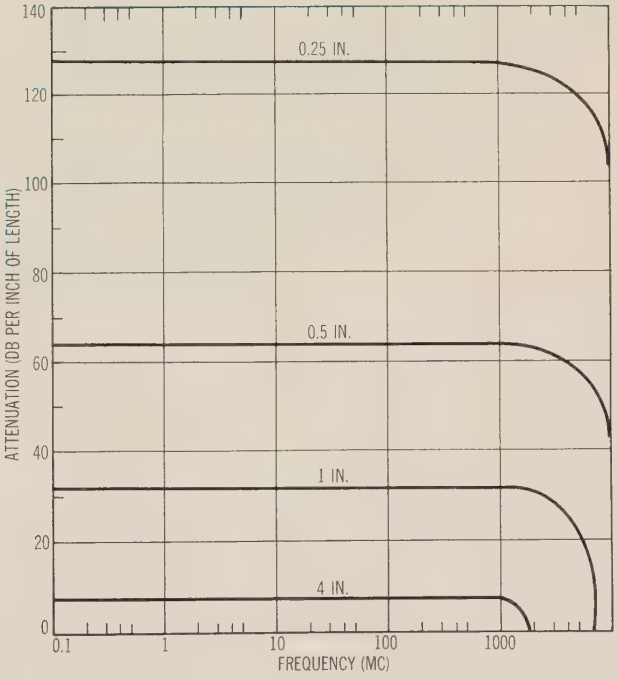


FIGURE 2: Collar shield for apertures in shielded enclosures and design curve for waveguide-type circular attenuators of various diameters. A collar 1 in. × 0.5 in. dia. for instance, gives 64 db of shielding to about 1000 mc.

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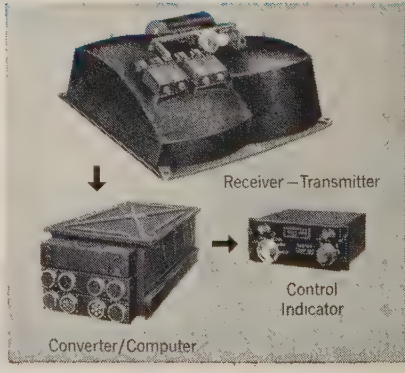

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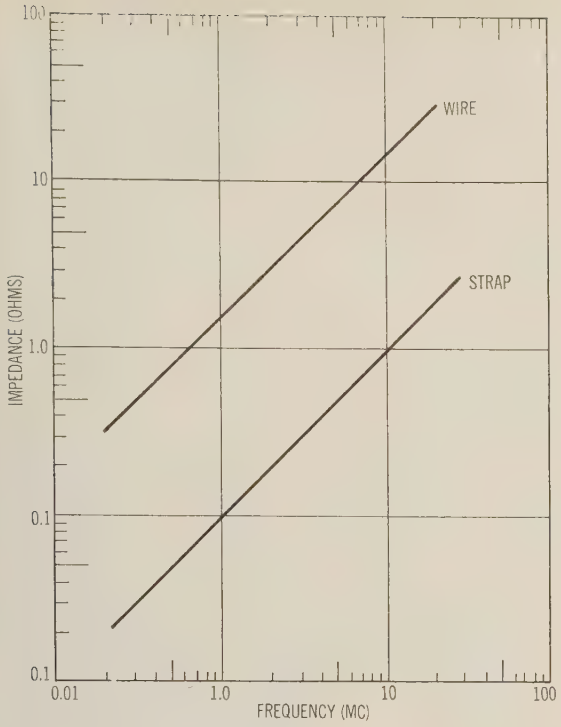

FIGURE 3: Impedance advantage of a 5½×1×1/16-in. beryllium copper bonding strap over an eight-inch length of No. 12 wire.

that heavy currents in the ground plane may develop ground loops that could be coupled into sensitive, low-frequency data circuits when multi-point grounding is used. Single-point grounding usually deals with this problem by grounding the cable shield at the source and letting it float at the load. This solution is poor—it clears up the ground-loop and low-impedance radiated field coupling problems, but makes high-impedance field coupling much worse.

Multi-point grounding meets all requirements. Normally, all AC neutrals and DC negative returns should be grounded to the frame or enclosure of the power source right next to, or as part of, the output terminal or connector. Separate AC neutrals and DC negative conductors can also be routed to individual units. These, however, must be grounded directly within each housing (near the connector) in the interests of personnel safety and to eliminate RF filtering of the type sometimes required in AC power and DC positive circuits.

Twisted pair protects data circuits

To protect sensitive, low frequency (DC to 10 mc) data circuits from large, unbalanced AC currents in the ground plane, use shielded twisted pair, which is available with low loss in this frequency range. Ground the shields at each end of the cable run and the signal return at the source only. With five amperes flowing in the ground plane, tests show no interference, nor should any be anticipated above this level.

Multi-point grounding has clear advantages over a floating, or single-point system:

- It makes for short ground connections.
- It lets you use a low-impedance ground return circuit.
- It provides low-impedance connections between components.
- It improves RF filtering.
- It reduces radiation and cross-talk in cables.

Cable shield continuity and shield ground connections directly affect cable radiation and cross-talk (*Fig. 4*). Cable shields must be continuous throughout the length of the cable run and grounded at each end. They must also be grounded on both sides of discontinuities. At connectors, they should be carried through on at least two cable pins or on the connector shell itself.

When several shielded leads are brought to a connector, a ring, or halo, around the shields can be used and connected to the connector shell. The shields should be grounded by lengths of less than one inch and must be grounded to a surface free of non-conducting finishes. Each shield should be covered with an insulation such as vinyl to prevent interference from contact with other shields or structures.

Airborne radar provides example

Suppression—An example will show most clearly how suppression can produce an interference-free design. Let's take the case of a simplified airborne radar consisting of synchronizer, indicator, modulator, receiver, receiver-transmitter, antenna, control boxes, and power supplies.

Sources of *synchronizer* interference are the timing oscillator, the gate generators (intensity, sweep, blanking), the sweep generator and sweep driver, the trigger generator, the range mark generator, and the range switching relays. The steps in suppressing this RFI are:

- Design all stages so that there are no signal amplitudes that exceed your requirement—if a 10-V trigger is optimum, for example, don't design for a 100-V amplitude.
- Decouple the plate and bias circuits of all stages (as close to the stage as possible).
- If tubes are used, route the filament wiring away from signal wiring. Ground one side of filament at each tube.
- Keep the signal wiring to component boards shorter than three inches.

Printed boards should provide peripheral grounding—a low-impedance ground path to chassis or case—when inserted in the mounting bracket.

- Shield the signal wiring to the exiting plug. The shield should be continuous over its run and grounded at each end with lengths of less than one inch.
- Ground the entering power neutrals or filaments (AC) inside the case (at the plug).
- Ground the low side of the actuating coil of any signal switching relay at the relay. The hot side should have an L- or T-type RF filter with an attenuation of at least 80 db from 0.150 to 400 mc. Alternatively, for relay contacts that switch power circuits, shield the hot lead from the relay to the actuating switch and connect a Zener diode, or use an RC network (if the current is under 50 ma) across the switch.

Indicator RFI sources

- Use AC rather than DC blower motors.

Sources of *indicator* RFI include sweep amplifiers, deflection circuits, video mixers (video range marks, intensity or blanking gates, sea-suppress gates, etc.), the indicator face, and control shafts. The suppression steps are:

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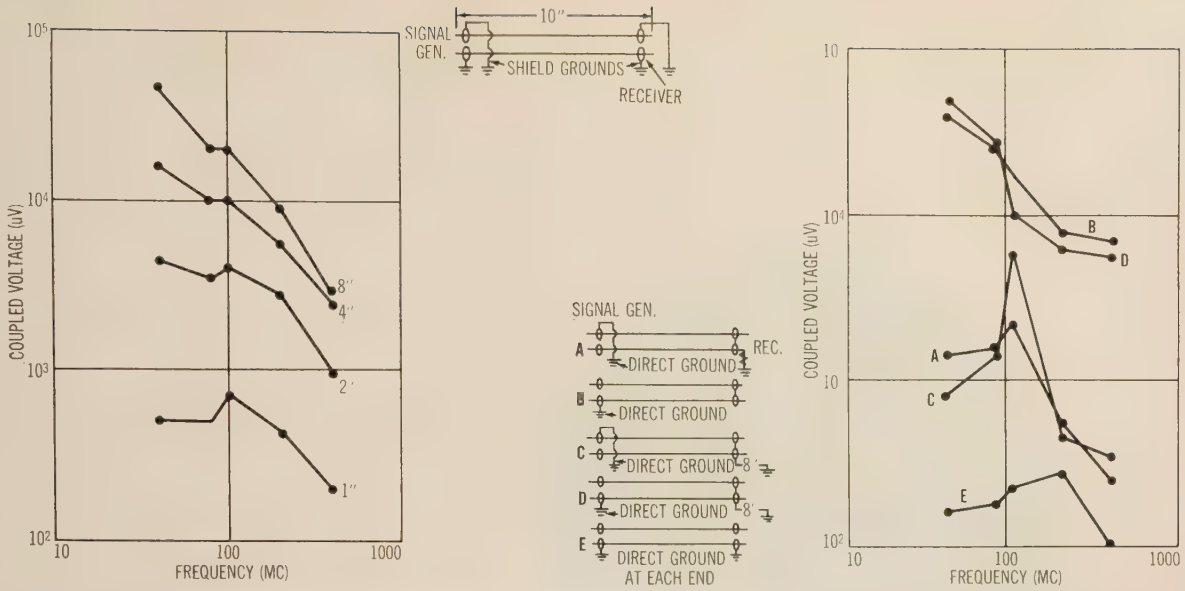


FIGURE 4: Cable coupling for various methods and lengths of shield termination at a signal generator output of 0.1 V.

- Decouple the plate and bias circuits of all stages.
- Use conductive, coated plexiglass with peripherally sputtered silver for the indicator face. Use metal gaskets or spring fingers for mating the face to the case.
- Ground the control shafts as they leave the case (*Fig. 2*).
- Handle the signal and power wiring as in the case of the synchronizer.
- Insert a despiking (L-type) IF filter, with capacitor toward the trigger source, in the grid lead of the thyratron switch.

Modulator & receiver-transmitter RFI

Interference sources in the *modulator* and *receiver-transmitter* are thyratrons, TRS, and ATRS, magnetrons, and local oscillators. The suppression steps are:

- Put the modulator, modulator supply, and receiver-transmitter in the same case.
- If the modulator and its supply are separated, use an RF filter at the high-voltage supply input to the modulator. If the modulator is separated from the transmitter, use triaxial cable for the high-voltage pulse to the transmitter. Ground the cable's internal shield at the thyratron cathode and carry it through to the low side of the transmitter input pulse transformer. Ground the external shield at each case. Use RF filters for all control and power circuits entering or leaving the cases.
- Use RF filters on the supply voltage of all ATR and TR tubes.
- When there is a receiver IF strip, use interstage decoupling, shield the case, and decouple the supply voltages to overcome the strip's sensitivity and tendency to spurious oscillations.

Sources of *antenna* RFI are the drive and servo motors and switching. The suppression steps are:

- Filter DC *drive* motors at the motor. If the filter is remotely located, use shielded leads between it and the motor.
- Shield the servo leads.
- Use coaxial cable carried through coaxial connectors for all signal wiring.

Control box sources

In *control boxes,* interference sources are the panel lights, controls, meters, rotary switches, and fuses. The suppression steps are:

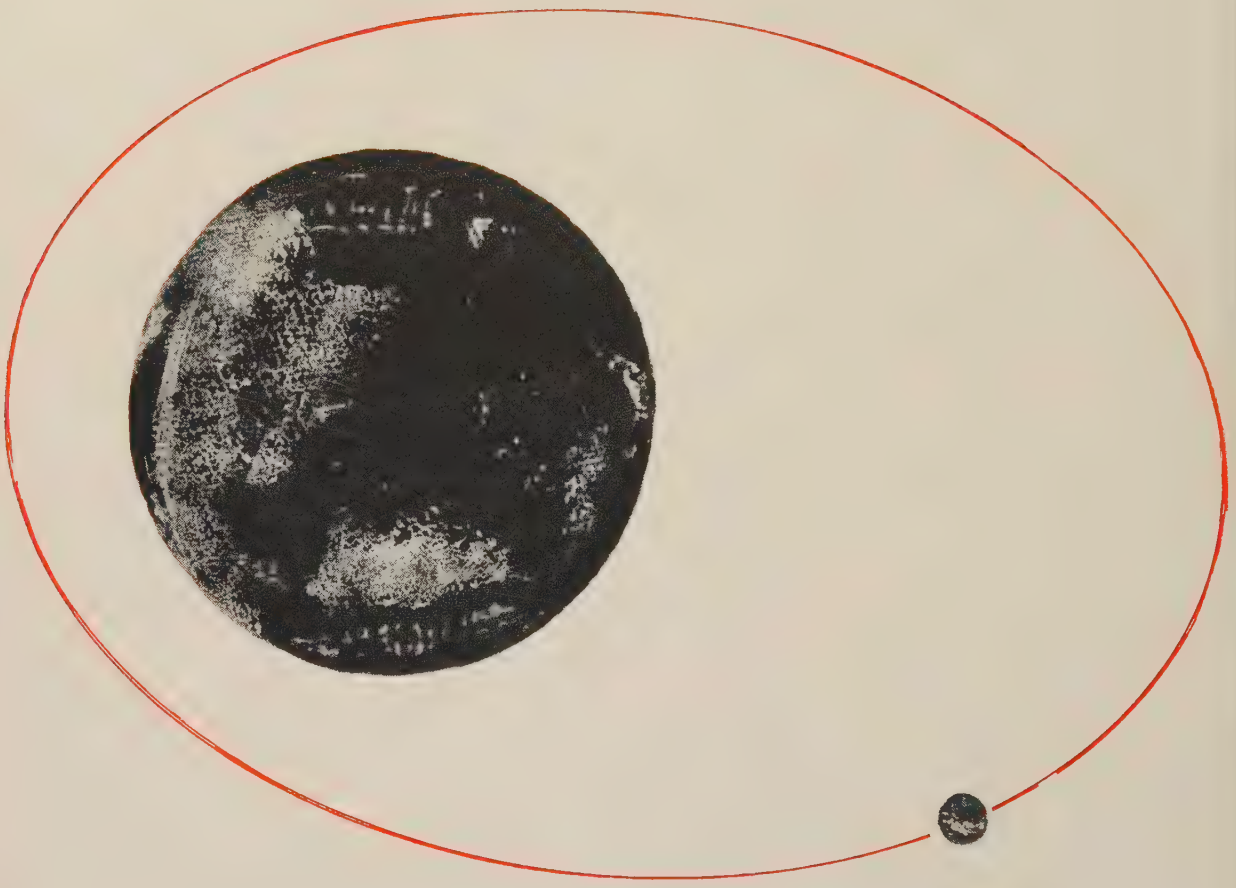
- Filter the panel-light leads. The filter mounting should be in shielded-hat form if rear-panel lights protrude.
- Ground the control shafts as they leave the cases.
- Handle meters and fuses in the same way as the panel lights.
- Handle rotary and snap switches as relay contact transient sources.

RFI sources in *power supplies* are silicon-diode, thyratron, and gas-tube rectifiers. Silicon-diode rectifiers are inherently noisy; the suppression methods for them range from brute-force input and output filtering to diode selection on the basis of operating characteristics.

For low-current applications:

- Use a capacitor bypass at each rectifier and a small resistor in series with the diode.
- Use inductances in series with the bridge supply voltage.
- In most cases, these methods require no power-source RF filtering, but they do require output ripple filtering.

For high currents, use a combination of audio ripple and RF filtering. When the load circuit impedance is high, a shunt resonant filter at the primary ripple frequency can replace the audio filter.



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Component Applications

by **D. R. Earles,** *Reliability Engineer, The Martin Co.**

BLOWERS

✔ Except when used with unusual components, design blowers into equipment as supply rather than exhaust—i.e. put blower on the cold side of the heat exchanger.

✔ For best blower proportions, use high design speeds for systems of high pressure drop, or of moderate pressure drop with small capacity. For operation between 18,000 and 15,000 rpm at maximum altitudes of 70,000 ft, use blowers designed for units with moderate pressure drop and of appreciable heat-dissipation capacity—on the order of three to five kilowatts.

✔ For minimum power requirements, small blower dimensions, and moderate operating speed, design heat-dissipating systems to get low-pressure drops that

* The Martin Co., Denver Div., Denver 1, Colo. The material on composition, film-type, and wirewound resistors was furnished directly to S/A by Raytheon, as was some of the material on resistors and capacitors in general and on transistors. Some of the material on transistors in turn was taken by Raytheon from K. Henney, C. Walsh, "Electronic Components Handbook," vol. 1; McGraw-Hill, '57. The section on varactors was taken from "Components Handbook," Space Technology Labs. Part of the material on waveguides was taken from "Military Equipment Design Practices," Bell Telephone Labs.

Check list for:

Blowers	Meters
Capacitors	Motors
Choppers	Potentiometers
Circuit breakers	Relays
Clutches (magnetic)	Resistors
Coils	Resolvers
Connectors (standard)	Servos
Diodes	Suppressors
Electron tubes	Switches
Failure modes	Synchros
Generic failure-rate distributions	Timers
Gyros	Thermistors
Joints (solder)	Transformers
Lamps	Transistors
	Varactors
	Waveguides

Table I: Codes and Common Applications for Capacitors*

	CM, Mica, Molded (Mil-C-5)	CP, Paper, Herm. (Mil-C-15)	CN, Paper, Non-Herm. (Mil-C-91)	CB, Mica, Button (Mil-C-10950)	CK, Ceramic (Mil-C-11015A)	CS, Electro-lytic, Ta. (Mil-C-26655)	CE, Electro-lytic, Al. (Mil-C-62)	CT, Air Trim (JAN C-92)	CC, Cer., Temp.-Comp. (JAN C-20)	CV, Cer., Var. (JAN C-81)	CJ, Electro-lytic, AC (Mil-C-3871)	CY, Glass (Mil-C-11272)
Blocking	✓	✓	✓									✓
Buffer	✓	✓										
Bypass	✓	✓	✓	✓	✓	✓	✓					✓
Coupling	✓	✓		✓	✓			✓	✓	✓		✓
Filtering	✓	✓	✓		✓	✓	✓					
Tuning	✓			✓				✓	✓	✓		✓
Motor Starting											✓	
Temperature compensation									✓			

*From Raytheon.

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Table II: Relative Cost of Fixed Resistors[1]

	Wattage (W)	Tol. (per cent)	Cost of 1-10 Units[2]		Cost of 100-500 Units[2]	
			Absolute	Relative to Composition Type	Absolute	Relative to Composition Type
Carbon composition	1	10	$0.18	1	$0.072	1
Deposited carbon film	1	1	$1.35	7.5	$0.55	7.6
Metal film	1	1	$3.00	17	$1.52	21
Precision wirewound	0.5	1	$1.25	7	$0.75	10.5
				Rel. to Power Wirewound Type		Rel. to Power Wirewound Type
Power wirewound	10	5	$0.85	1	$0.50	1
Power film	7	5	$4.35	5	$1.74	3.5
Power-finned, chassis mounting	25	1	$1.50	1.8		

(1)From Raytheon. (2)For Mil spec quality.

do not exceed 1.0 in. of water at sea level. Cooling with a large air volume having limited temperature rise is better than cooling with smaller air quantities and larger temperature rises.

- To produce constant heat dissipation, preferably at constant surface temperature of the equipment, use a centrifugal blower.

- Use centrifugal blowers to cool electronic units over wide altitude ranges; they are more adaptable to a wide range of control.

- Where space is critical, use an axial fan.

- Do not use a propeller fan where air is to be moved through restricted areas that develop back pressure appreciably in excess of 0.15 to 0.25 in. of water column.

- Do not use commutator-type fan motors in volatile, combustible, or explosive atmospheres.

- For smallest diameters and best-proportioned impellers, do not use blowers of large cooling capacity. If operating speed increases with design altitude, the impeller diameters of blower units with cooling capacities on the order of one kilowatt can be held between four and five inches. Increased cooling capacity requires larger diameters, not for greater pressure but to reduce the operating speed to maintain reasonable impeller width.

- Prevent restriction of air flow through the chamber to be cooled.

CAPACITORS

- Do not let the sum of the highest DC voltage plus the peak AC amplitude voltage to be applied exceed the working voltage rating of the capacitor. Be sure that the rated working voltage is at least 20 per cent higher than the expected sum of these voltages on all except electrolytics.

- The safe peak voltage may decrease with aging, increase in temperature, an increase of area of dielectric, higher frequencies of applied voltage, a decrease in pressure, and entrance of moisture into the capacitor. It is often necessary to derate the capacitor from the specified voltage to provide the desired performance for the required time. Short-duration transient voltages cannot be neglected in capacitor applications.

- Operation of capacitors above the corona-starting voltage reduces life and produces noise. Liquid-impregnated dielectrics have a higher corona-starting voltage than dry solid dielectrics.

- Capacitors for AC and pulse operation require special ratings and tests; these are not covered in most military specs.

- Find out the effect of frequency on the operation of the capacitor, particularly the relationship between maximum rated current and frequency. The current through a capacitor varies directly with the frequency. Operating a capacitor at higher than design frequency results in inefficiency and overheating.

- Use capacitors designed for UHF if UHF pulses are to be applied. Otherwise, the capacitors may puncture.

- Operation of capacitors in parallel in circuits with fast rise times or transients may result in transient oscillations.

- Shunt a large capacitor with a small one. Use the shortest possible leads, looped or crossed, for maximum bypassing effect. This is necessary because of the large inherent inductance of some capacitors.

- Avoid excessively high operating temperatures—they induce accelerated capacitance drift, lower dielectric strength, lower corona levels, lower insulation resistance, and shorten life. The life of a capacitor is inversely proportional to approximately the seventh to ninth power of the temperature.

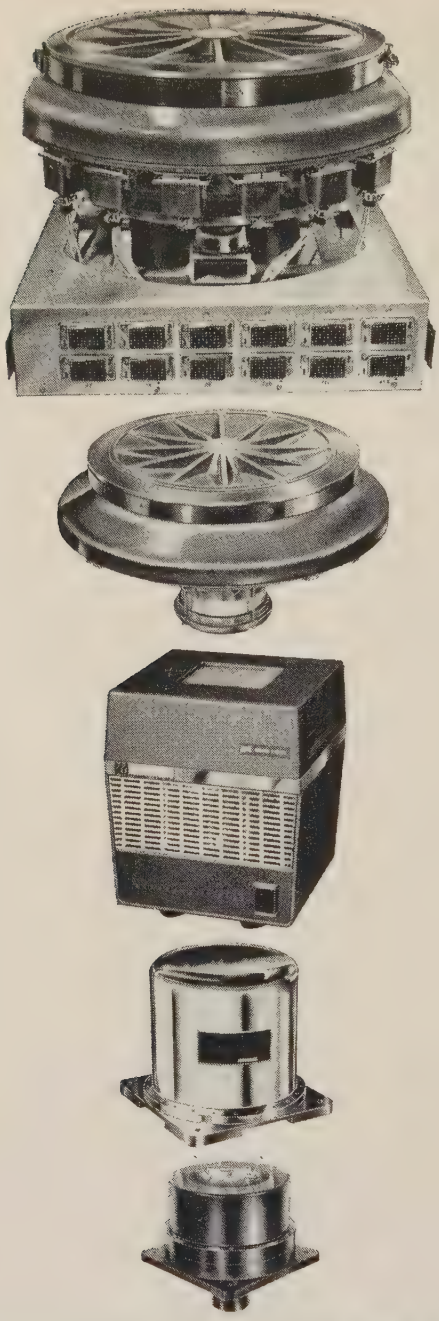
- Lacking failure-rate data, you can estimate that capacitor life decreases by a factor of two for each 10 deg C rise. The rule is derived from the chemical law covering the speed of chemical reactions. It should never be used outside the temperature range specified by the manufacturer, since different chemical reactions may take place at extreme temperatures.

- Use rigid capacitor containers for changing pressure levels. Any pronounced variation in pressure on non-rigid containers may change capacitance.

- Always use hermetically sealed paper capacitors.

- Do not store capacitors in high humidity. The insulating material may absorb moisture and silver ion migration may occur when the capacitors are used.

- Oil- or acid-filled units should not be subjected to severe mechanical stresses. Fluid leakage can destroy



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the capacitor and adjacent components. Liquid-filled units should not be used inverted—internal corona may result.

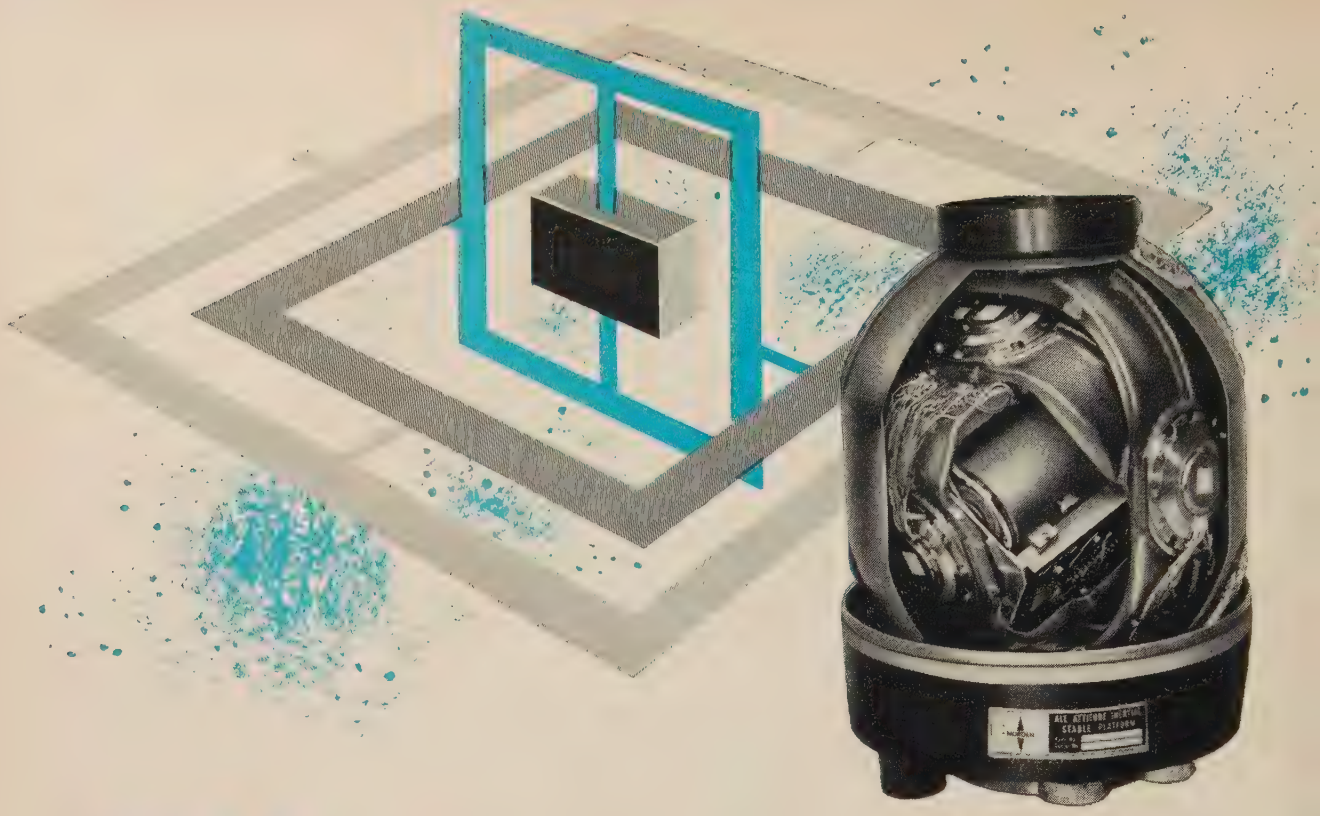
Table I summarizes the kinds of capacitors commonly manufactured to Mil specs and their normal applications.

CERAMIC CAPACITORS

✔ Avoid operating capacitors above the corona-starting voltage in AC or pulsating DC circuits—this reduces life and produces noise.

Failure Modes of Electronic Components

	Vibration Effects	Shock Effects	Temperature Effects	Humidity Effects	Salt-Spray Effects	Storage Effects
Blowers	Brinelling of bearings		Shorts; lubricant deterioration	Corrosion	Corrosion	Lubricant deterioration
Capacitors Ceramic	Increased lead breakage; piezoelectric effect; body and seal breakage	Lead breakage; piezoelectric effect; body and seal breakage	Changes in dielectric constant and capacitance; lowered insulation resistance with high temperature		Corrosion; shorts	Decreased capacitance; silver-ion migration
Electrolytic	Increased lead breakage; seal damage; current surges	Lead breakage; seal damage; current surges	Increased electrolyte leakage; shortened life; increased current leakage; large change in capacitance; increased series resistance with low temperature	Decreased insulation resistance; increased dielectric breakdown; increase in shorts	Corrosion; shorts	Electrolyte deterioration; shortened life; increased chances for explosion; shorts
Mica	Lead breakage	Lead breakage	Increased insulation resistance; silver ion migration; drift	Silver migration	Shorts	Change in capacitance
Paper	Increase in opens and shorts; lead breakage	Opens; increased dielectric breakdown; shorts; lead breakage	Changes in capacitance; increased oil leakage; decreased insulation resistance; increased power factor	Decreased insulation resistance; increased power factor	Shorts	Decreased insulation resistance; increased dielectric breakdown; increase in shorts
Tantalum	Opens; shorts; current surges; lead breakage	Opens; lead breakage; shorts; current surges	Electrolyte leakage; change in capacitance; insulation resistance; series resistance	Decreased insulation resistance; increased dielectric breakdown; increase in shorts	Corrosion	Electrolyte leakage; decreased insulation resistance; increase in shorts
Choppers	Increase in phase angle and dwell time	Contacts open; change in phase angle and dwell time	Decrease in phase angle; variation in dwell time		Corrosion	Change in phase angle
Circuit breakers	Premature activation	Premature close or open	Failure to function; premature function	Corrosion	Corrosion	Change in characteristics
Clutches, magnetic	Creep	Intermittent operation	Hot spots in coil	Falloff in torque	Binding	
Coils	Loss of sensitivity; detuning; breaking of parts, leads, and connectors	Lead breakage; detuning; loss of sensitivity'	Warping; melting; instability; change in dielectric properties	Electrolysis; corrosion	Corrosion; electrolysis	
Connectors Standard	Separation of plugs and receptacle; insert cracks; opening of contacts	Opening of contacts	Flashover; dielectric damage	Shorts; fungus; corrosion of contacts; lowered insulation resistance	Corrosion	Deterioration of seals; corrosion of contacts
Interstage	Insert cracks; opening of contacts	Opening of contacts	Flashover; dielectric damage	Shorts; fungus; corrosion of contacts; lowered insulation resistance	Corrosion	Deterioration of seals; corrosion of contacts
Crystals	Opens	Opens	Drift; nicrophonic	Drift		Drift
Crystal holders	Intermittent contact	Intermittent contact		Change of capacity		
Diodes	Opens	Opens	Change in voltage breakdown; increased current leakage; increase in opens and shorts	Increased current leakage	Corrosion of lead and case	Increased current leakage
Gyros	Drift	Drift; leaks	Drift			Induced drift
Insulators	Cracking; elongation	Cracking	Epoxy cracking; ferrite separation (arcing); moisture condensation (insertion loss)	Moisture condensation (insertion loss); reduction in dielectric strength and insulation resistance	Reduction in dielectric strength and insulation resistance	
Joints, solder	Cracking; opens	Cracking; opens	Loss of strength	Fungus	Corrosion	At room temperature, strength increased; at low temperature, strength decreased
Magnetrons	Arcing; "FM"-ing	Seal breakage		Arcing	Corrosion	Leaks; gassiness



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Failure Modes of Electronic Components (cont.)

	Vibration Effects	Shock Effects	Temperature Effects	Humidity Effects	Salt-Spray Effects	Storage Effects
Motors	Brinelling of bearings; loosening of hardware		Shorts; opens; deterioration of lubricants	Binding of bearings; shorting of windings; corrosion	Corrosion; binding of bearings	Oxidation
Potentiometers	Increased noise; change in torque and linearity; wiper brush bounce; open circuit	Increased noise; change in torque, linearity, and resistance; open circuit	Increased noise; change in torque, linearity, and resistance; decreased insulation resistance with high temperature	Increased noise; change in torque, linearity, and resistance; decreased insulation resistance	Decreased insulation resistance; increased corrosion; binding	Increased noise; change in torque, linearity, and resistance; decreased insulation resistance
Relays	Contact chatter	Contact opening or closing	Opens or shorts; decreased insulation resistance with high temperature	Decreased insulation resistance	Corrosion of pins	Oxidation of contacts causes open circuits; decreased insulation resistance
Resistors	Lead breakage; cracking	Cracking; opens	Increased resistance; opens; shorts	Increased resistance; shorts; opens	Change in resistance; lead corrosion	Change in resistance
Resolvers	Intermittent brush operation; brinelling of bearings; cracking of terminal board; loosening of hardware	Intermittent brush operation; cracking of terminal board; loosening of hardware	High breakaway voltage; shift in electrical axis; opens; shorts; deterioration of lubricants	Corrosion that causes expansion and blistering of potting compound; shorting of winding; pinion corrosion	Corrosion; binding	Oxidation; deterioration of lubricants
Servos	Brinelling of bearings; loosening of hardware; cracking of terminal board	Loosening of hardware; cracking of terminal board	Oil throw-out; breakdown of grease; high breakaway voltage	Corrosion that causes blistering of potting compound; shorting of winding; pinion corrosion	Corrosion that causes rotor binding; salt crystals in bearings and on rotor	Deterioration of grease with age; oxidation of brushes and slip rings
Switches	Contact chatter	Contact opening	Oxidation of contacts	Pitted contacts; arcing	Oxidation and corrosion; pitted contacts	Oxidation of contacts
Synchros	Intermittent brush operation; cracking of terminal board; brinelling of bearings; loosening of hardware	Intermittent brush operation; cracking of terminal board; brinelling of bearings; loosening of hardware	High breakaway voltage	Corrosion that causes expansion and blistering of potting compound; shorting of winding; pinion corrosion	Corrosion	Oxidation
Thermistors	Lead breakage; case cracking; open circuit	Lead breakage; case cracking; open circuit	Increased shorts and opens	Change in resistance	Lead corrosion; change in resistance	Change in resistance
Transformers	Shorts; opens; modulation of output	Shorts; opens; modulation of output	Reduced dielectric; opens; shorts; hot spots; malformation	Corrosion; fungus; shorts; opens	Corrosion; shorts; opens	Deterioration of potting and dielectric
Transistors	Opens; functional disintegration	Opens; seal breakage	Increased leakage current; changes in gain; increase in opens and shorts	Increased leakage current; decreased current gain. If sealed, no effect	Increased leakage current; decreased current gain. If sealed, no effect	Seal leakage; changes in parameters
Tubes, electron	Opens; shorts; microphonics; loosening of elements; changes in characteristics	Opens; shorts; changes in characteristics	Shorts; temporary change in characteristics; formation of leakage paths; increased contact potential; shorting of heater life; gassiness; bulb puncture	Change in characteristics; leakage path; arcing	Shorts; corrosion; leakage path; arcing	Change in characteristics; leaks; gassiness
Vibrators	Intermittent	Intermittent	Lag	Case corrosion	Case corrosion	Decrease in frequency

✔ Do not expose the silver electrodes in the capacitor to high humidities and high DC potentials. Silver-ion migration may take place and short-circuit capacitors after a relatively short time. At low humidities and low DC potential, long life (10 years) can be anticipated.

✔ Be careful when soldering leads. Excessive heat may damage the phenolic insulation and weaken the plate-to-lead contact. Sudden changes in temperature can crack the case or the ceramic dielectric.

✔ Consider that, from the time of firing, the dielectric constant of the materials used may decrease. After 1000 hr, the capacitance may be as low as 75 per cent of the original value. The aging rate decreases considerably during the 1000 to 10,000-hour decade. Some of this capacitance may be recovered if the operating

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eters
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oscilloscopes, and stroboscopes
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completely self-contained

Measures	Range (peak-to-peak)	Freq
Jerk	30-300,000 in./sec³	2-20
Acceleration	0.3-300,000 in./sec²	2-120
Velocity	0.03-30,000 in./sec	2-120
Displacement	0.003-300 in. 0.00003-30 in.	2-120 20-12

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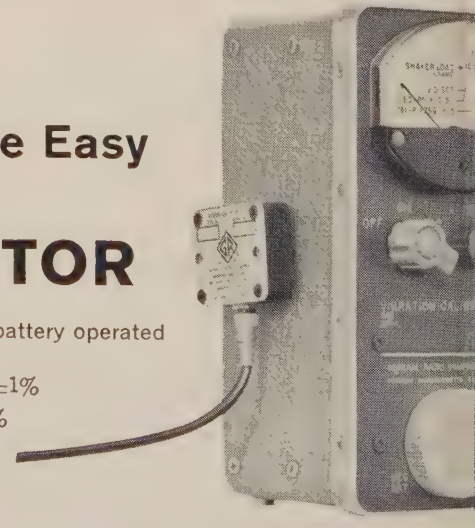

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temperature is raised, but the aging begins again when the temperature drops.

✔ Don't fail to consider the change in dielectric constant due to changes in temperature, voltage, frequency, time, ferro- and piezoelectric effects, and the effects of humidity on insulation resistance.

ELECTROLYTIC CAPACITORS

✔ Use only limited derating. Severe derating for any length of time may necessitate reforming.

✔ Minimize danger to personnel and equipment from explosions. Although electrolytic capacitors have vents designed to open at dangerous pressures, explosions of considerable violence can occur from gas pressure or spark ignition of free oxygen and hydrogen liberated at the electrodes.

✔ Ground capacitors with uninsulated cases or protect them by an insulating sleeve. Even if the case is not connected to any circuit element, a high potential may develop between a floating case and ground by leakage between capacitor elements and the case.

✔ Do not use an electrolytic capacitor as a voltage regulator.

✔ Do not operate electrolytic capacitors at temperatures above 55 to 65 deg C. Doing so will eventually increase the series resistance and shorten the life of the capacitor.

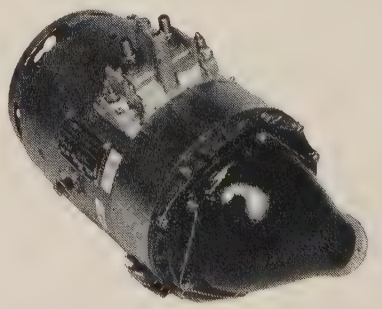
Generic Failure-Rate Distributions of Electronic Components

	Rate per Million Hours				Rate per Million Hours		
	Upper Extreme	Mean	Lower Extreme		Upper Extreme	Mean	Lower Extreme
Accelerometers, strain gage	21.4	8.0	1.00	Connectors			
Actuators	13.7	5.1	0.35	Electric	0.47/pin	0.2/pin	0.03/pin
Booster servo	33.6	12.5	0.86	AN type	0.385/pin	0.2125/pin	0.04/pin
Sustainer servo	33.6	12.5	0.86	Coaxial	0.3650/pin	0.2125	0.06
Small utility	9.6	3.6	0.17	Interstage	0.94/pin	0.4/pin	0.06/pin
Large utility	18.5	6.9	0.60	Test point	0.082/pin	0.05/pin	0.02/pin
Adapters, waveguide	9.31	3.475	0.139	Umbilical	4.7/pin	2/pin	0.03/pin
Alternators	2.94	0.7	0.033	Couplers, Directional	3.21	1.6375	0.065
Blowers	3.57	2.4	0.89	Rotary	0.049	0.025	0.001
Boards, terminal	1.02	0.0626	0.01	Crystals	0.14	0.10	0.04
Brushes, rotary devices	1.11	0.1	0.04	Oscillator	1.1	0.60	0.10
Capacitors, fixed				Rectifier	0371	0.2	0.03
Under 600 V	0.018	0.01	0.001	RF	0.6	0.3	0.025
Over 600 V	0.486	0.27	0.027	Selenium	0.42	0.3	0.12
Over 1000 V	2.385	1.325	0.1325	Manganese copper sulfide	0.07	0.05	0.02
Capacitors, ceramic	0.213	0.1	0.063	Silicon diode	0.28	0.20	0.08
Under 600 V	0.133	0.0625	0.040	Crystal ovens	0.17	0.05	0.03
Capacitors, electrolytic	0.054	0.035	0.003	Delay lines			
Capacitors, mica	0.132	0.075	0.018	Fixed	0.25	0.1	0.08
Under 600 V	0.066	0.0375	0.009	Variable	4.62	3.00	0.22
Button	0.057	0.03	0.003	Diodes	1.47	0.2	0.16
Quality foil	0.076	0.045	0.014	Germanium	0.38	0.3	0.23
Silvered	0.141	0.083	0.025	Selenium	0.6	0.2	0.11
Capacitors, high-reliability, paper nylon, 300-600 V	0.014	0.01	0.006	Silicon	0.25	0.2	0.15
Capacitors, oil-filled	0.48	0.30	0.12	Silicon carbide	0.55	0.02	0.009
Capacitors, paper	0.034	0.025	0.016	Surge limiting, standoff, logic	0.437	0.2	0.08
Under 600 V	0.04	0.0125	0.01	Zener	0.03	0.15	0.08
Capacitors, high-reliability, porcelain	1.02	0.09	0.04	Disconnects, quick	2.1/pin	0.4/pin	0.09/pin
Capacitors, tantalum	0.83	0.600	0.27	Duplexers, rat race	5.38	4.0	3.23
Plain foil, non-polar	2.00	0.100	0.08	Dynamotors	5.46	2.8	1.15
Plain foil, polar	2.10	0.100	0.075	Fans, exhaust	9.0	0.225	0.21
Etched foil, polar	2.20	0.100	0.07	Filters			
Capacitors, variable	0.28	0.1625	0.09	Electric	3.00	0.345	0.140
Ceramic	0.35	0.155	0.08	Light	0.80	0.20	0.12
Choppers	0.80	0.5	0.31	Mechanical	0.8	0.3	0.045
Circuit breakers	0.40	0.1375	0.045	Fuses	0.82	0.5	0.30
Thermal	0.50	0.3	0.25	Gaskets			
Clutches	1.1	0.04	0.06	Cork	0.077	0.04	0.003
Magnetic	0.93	0.6	0.45	Impregnated	0.225	0.1375	0.05
Slip	0.94	0.3	0.07	Monel mesh	0.908	0.05	0.0022
Coils	0.088	0.050	0.033	O-ring	0.03	0.02	0.01
Choke	0.100	0.02	0.01	Phenolic	0.07	0.05	0.01
Filter choke	0.25	0.03	0.012	Rubber	0.03	0.02	0.011
Plate choke	0.031	0.02	0.009	Gimbals	12.0	2.5	1.12
Motor winding	0.045	0.03	0.01	Gyros	7.23	4.90	0.85
RF	0.05	0.01	0.005	Rate	11.45	7.5	3.95
Repeater	0.20	0.1	0.03	Reference	25.0	10.0	2.50
Tuning	0.2858	0.15	0.0142				

BENDIX DC GENERATORS HAVE FLOWN MILLIONS OF PASSENGER MILES ON GRUMMAN GULFSTREAMS

Note to Corporate Aircraft Owners: These Bendix® DC generators, specifically designed to meet the needs of corporate aircraft, are applicable to a wide range of single- and multi-engine aircraft. Used in a complete DC generating system incorporating regulating and control components, they provide the type of specialized DC electric power required by the Gulfstream.

Bendix 30E20-41 Generator (shown) has the following rating: 9KW, 30 volts, 300 amps. Provides continuous duty over a speed range of 4000 to 8000 rpm with air blast cooling of 6 inches of H_2O at 40°C. Designed for 28-volt, DC electrical systems. Weight: 46 lbs. (max.)



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THE Bendix CORPORATION

- Do not use electrolytics at low barometric pressures and low temperatures.
- Use etched-foil polar types for the smallest size of a given capacitance. Polar types have twice the capacitance of nonpolar types; etched-foil types may have 500 per cent greater capacitance for the same size. Plain foil types have better capacitance-temperature characteristics.
- Use polar types in unidirectional polarity circuits. Very low operation (under five volts) causes polar types to give nonpolar capacitance.
- Discard polar capacitors that have been subjected to voltage reversals.
- Re-form all electrolytics after long periods of inactivity; this necessity is more evident with aluminum-foil types than with tantalum.
- Use foil tantalum electrode dielectric wherever possible.

MICA CAPACITORS

- Mica capacitors can be operated above the corona-starting voltage with satisfactory life, since the mica is corona- and arc-resistant. However, the internal discharges due to corona produce noise and spurious signals that may cause circuits to malfunction.
- Do not use foil mica capacitors where stability is

Generic Failure-Rate Distributions of Electronic Components (cont.)

	Rate per Million Hours		
	Upper Extreme	Mean	Lower Extreme
Inductors	0.031	0.02	0.011
High-voltage circuits	0.73	0.4	0.07
Solenoid	0.091	0.04	0.02
Insulation	0.72	0.50	0.011
Insulators	0.08	0.05	0.03
Feedhorn	0.30	0.075	0.051
Inverters	110.0	40.0	10.70
Iris, waveguide	0.08	0.0125	0.003
Jacks	0.02	0.01	0.002
Magnetic amplifiers	0.855/cone	0.085/cone	0.02/cone
Magnets	7.11	5.65	2.02
Meters, electric	5.77	1.375	1.35
Motors	7.5	0.625	0.15
Blower	5.5	0.2	0.05
Electric	0.58	0.3	0.11
Hydraulic	7.15	4.3	1.45
Servo	0.35	0.23	0.11
Stepper	0.71	0.37	0.22
Mounts, vibration	1.60	0.875	0.20
Potentiometers	12.5	3.0	0.70
Carbon-deposited	0.75	0.25	0.10
Composition	0.30	0.10	0.04
Computing	14.70	5.0	1.18
Motor-driven	12.60	5.485	1.71
Molded	15.7	7.0	4.4
Wirewound	2.05	1.4	0.65
Wirewound, miniature	2.00	1.2	0.72
Wirewound, R = 10 K, miniature	1.92	1.19	0.53
Wirewound, R = 10 K, 20 K, miniature	2.02	1.21	0.81
Wirewound, R = 20 K, miniature	2.04	1.23	0.88
Radomes	5.22	3.0	0.78
Reactors			
Charging	2.220	1.3875	0.555
Low-frequency choke	0.280	0.175	0.070
Saturable	0.32	0.14	0.12
Rectifiers	0.75	0.6	0.28
Selenium	1.60	1.1625	0.32
Relays			
Armature	0.5/cs	0.3/cs	0.11/cs
General purpose	0.48/cs	0.25/cs	0.10/cs
Heavy-duty solenoid	0.81/cs	0.5/cs	0.30/cs
Hermetically sealed	0.19/cs	0.04/cs	0.02/cs
Midget	0.54/cs	0.25/cs	0.145/cs
Millisecond	0.84/cs	0.44/cs	0.18/cs
Miniature	0.25/cs	0.06/cs	0.03/cs
Miniature, high-speed	1.13/cs	0.7/cs	0.42/cs
Power	4.10/cs	0.3/cs	0.15/cs
Sensitive	0.89/cs	0.4/cs	0.22/cs
Time delay	0.749/cs	0.39/cs	0.156/cs

	Rate per Million Hours		
	Upper Extreme	Mean	Lower Extreme
Relays (cont.)			
Thermal	1.0/cs	0.4/cs	0.12/cs
Resistors,			
Carbon deposit	0.57	0.25	0.11
Composition	0.15	0.043	0.017
Film	0.058	0.03	0.017
Fixed	0.07	0.03	0.01
Fixed high wattage	0.065	0.028	0.009
Precision tapped	0.292	0.125	0.041
Thyrite	0.153	0.10	0.047
Wirewound	0.165	0.087	0.046
Wirewound, accurate	0.191	0.091	0.052
Wirewound, power	0.076	0.04	0.021
Wirewound, precision	0.114	0.06	0.032
Resolvers	0.07	0.04	0.02
Rheostats	0.19	0.13	0.07
Seals			
Rotating	1.12	0.7	0.25
Sliding	0.92	0.3	0.11
Servos	3.4	2.0	1.1
Shafts	0.62	0.35	0.15
Sockets, electron-tube	0.009/pin	0.005/pin	0.002/pin
Solenoids	0.55	0.05	0.036
Switches	0.14/cs	0.5/cs	0.009/cs
Cam	0.12/cs	0.075/cs	0.048/cs
Interlock	1.0/cs	0.5/cs	0.25/cs
Micro	0.50/cs	0.25/cs	0.09/cs
Push button	0.11/cs	0.063/cs	0.043/cs
Rotary	0.660/cs	0.175/cs	0.118/cs
Motor-driven	0.292/cs	0.190/cs	0.128/cs
Sensitive, large	0.072/cs	0.045/cs	0.021/cs
Sensitive, small	0.124/cs	0.06/cs	0.045/cs
Slide (plunger)	0.112/cs	0.054/cs	0.041/cs
Thermal	0.261/cs	0.161/cs	0.114/cs
Toggle	0.123/cs	0.06/cs	0.015/cs
Wire guide	0.83/cs	0.50/cs	0.38/cs
Synchros	0.61	0.35	0.09
Resolver	1.94	1.1125	0.29
Tachometers	0.55	0.3	0.25
Terminals, standoff	0.0009	0.0005	0.0003
Thermisters	1.40	0.6	0.20
Thermostats	0.14	0.06	0.02
Timers			
Electronic	1.80	1.2	0.24
Electromechanical	2.57	1.5	0.79
Pneumatic	6.80	3.5	1.15
Transducers	45.0	30.0	20.0
Pressure	52.2	35.0	23.2
Strain gage	20.0	12.0	7.0
Thermister	28.00	15.0	10.0

MICROWAVE PROBLEM?
GEL MAY HAVE ALREADY SOLVED IT

General Electronic Laboratories has encountered and solved a variety of microwave design problems covering receivers, transmitters, antennas and associated servo control systems.

Research and development at the forefront of the state of the art is continuing at company laboratories in Cambridge, Mass., and Silver Spring, Maryland.

Extensively equipped facilities have been developed for testing, model shop work, and manufacturing. Many special manufacturing services are also available like electroforming for the production of cavities, feeds, horns and intricate microwave structures; and fiberglassing for radomes and reflectors.

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Broad-band coaxial horns, bi-circularly polarized
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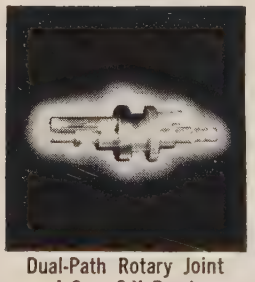
For assistance with your microwave problems, write to:

GENERAL ELECTRONIC LABORATORIES, INC.
18 Ames Street, Cambridge 42, Mass.

1-4 Kmc Coaxial Feed


Dual-Path Rotary Joint
L-S or C-X Band

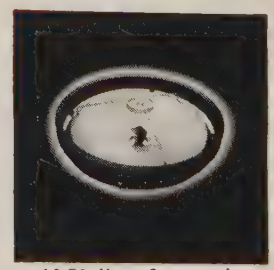
GEL

Servo-Controlled
Passive Reflector

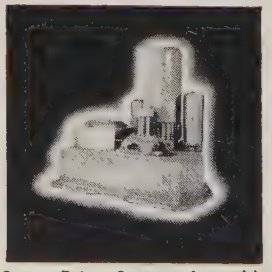
1-11 Kmc High-Gain
Antenna Assembly

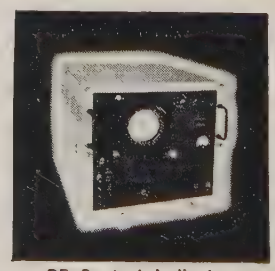
4-12 Kmc Coaxial Feed

Telemetering
Antenna Assembly


10-50 Kmc Cassegrain
Antenna Assembly

Parametric Frequency
Doubler — 15 to 20 Kmc Output


Servo Drive System Assembly


DF Control Indicator

Electroformed
Tuning Cavities

No. 192 on Reader Service Card

critical. Foil micas are less stable than silver micas, and larger drifts can be anticipated, particularly at higher temperatures.

✔ Avoid excessive moisture. The phenolic compounds used for the molded cases of these capacitors transmit moisture and silver ion migration may occur.

✔ Use button-mica capacitors only when their low inductance is essential.

PAPER CAPACITORS

✔ Use the extended-foil type when more stable low-voltage characteristics, less series-contact resistance, and lower residual inductance are needed.

✔ Use the inserted-tab type when a small reduction in unit volume is needed.

✔ Do not use the inserted-tab type for low-voltage application (below 10 V).

✔ Use the metallized paper capacitor with extreme care. Do not use in tuned circuits, in circuits where large and frequent transients may occur, in RF coupling, or where high leakage currents cannot be tolerated.

✔ In use, make sure that the final ratings (after derating and safety factors have been applied) cannot be exceeded under such circumstances as the heater of a tube being open, a tube being removed, or the misadjustment of a variable resistor while the equipment is energized.

Generic Failure-Rate Distributions of Electronic Components (cont.)

	Rate per Million Hours		
	Upper Extreme	Mean	Lower Extreme
Transformers	0.02	0.2	0.07
AF	0.04	0.02	0.01
IF	0.31	0.1	0.035
Isolation	0.093	0.03	0.011
Output	2.08	1.04	0.46
Power	2.08	1.04	0.46
Power, high-voltage	1.88	0.94	0.407
Power, low-voltage	0.60	0.3	0.13
Pulse, high-voltage	0.235	0.15	0.065
Pulse, low-voltage	0.235	0.15	0.065
Precision	0.814	0.2625	0.092
Variable	0.31	0.1	0.035
Transistors	1.02	0.61	0.38
Transistors, germanium	1.91	0.9	0.60
2N1302	0.879	0.414	0.276
2N1303	0.709	0.334	0.223
2N1304	0.879	0.414	0.276
2N1305	0.700	0.334	0.223
2N1306	0.879	0.414	0.276
2N1307	0.709	0.334	0.223
2N1308	0.879	0.414	0.276
2N1309	0.709	0.334	0.223
Transistors, silicon	0.86	0.5	0.27
2N117	1.44	0.84	0.45
2N118	1.44	0.84	0.45
2N119	1.44	0.84	0.45
2N120	1.44	0.84	0.45
2N332	1.03	0.6	0.32
2N334	1.11	0.6	0.025
2N335	1.11	0.6	0.025
2N336	1.11	0.6	0.025
2N337	0.67	0.5	0.16
2N338	0.67	0.5	0.16
2N339	0.67	0.5	0.14
2N340	0.67	0.5	0.14
2N341	0.67	0.5	0.14
2N342	0.67	0.5	0.14
2N343	0.67	0.5	0.14
2N696	0.84	0.7	0.084
2N697	0.84	0.7	0.084
2N497	0.84	0.74	0.21
2N498	0.84	0.74	0.21
2N656	0.84	0.74	0.21
2N657	0.84	0.74	0.21
Transistors, used as amplifiers	0.84	0.5	0.31
Transistors, used as switches	0.71	0.4	0.10
Tubes, electron			
Cathode-ray, electric deflection	2.00 + no. of guns	1.00 + no. of guns	0.96 + no. of guns
Cathode-ray, magnetic deflection	3.10 + no. of guns	1.65 + no. of guns	0.94 + no. of guns

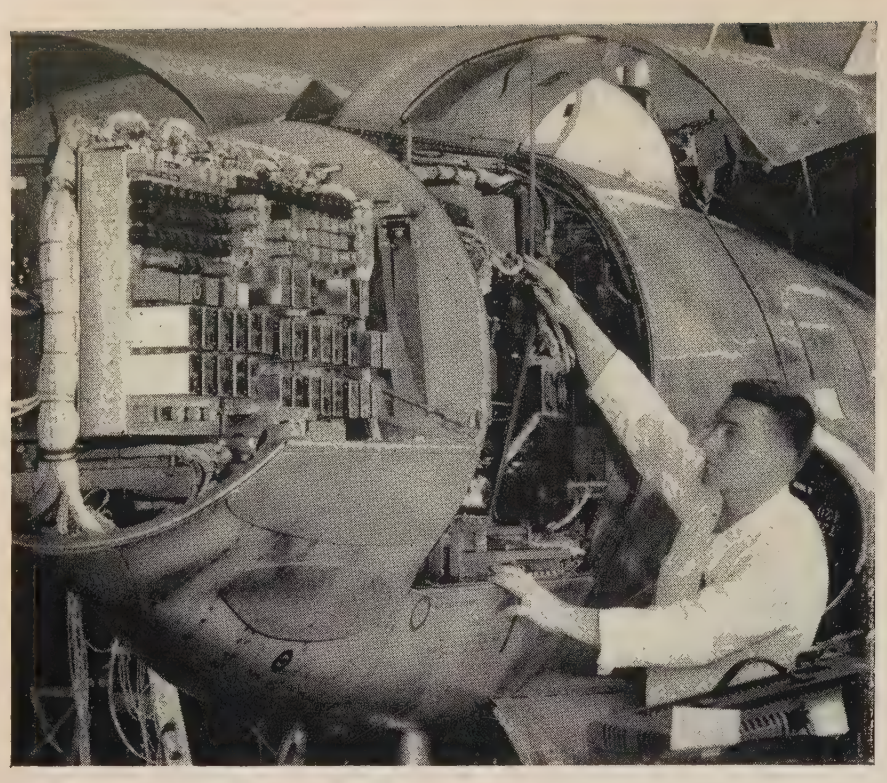
	Rate per Million Hours		
	Upper Extreme	Mean	Lower Extreme
Commercial, single diode	2.20	0.80	0.24
Commercial, double diode, ½	1.04	0.60	0.32
Commercial, double diode, tied	1.89	1.0	0.38
Commercial, single triode	2.26	1.3	0.67
Commercial, double triode, ½	1.74	1.0	0.52
Commercial, double triode, tied	3.88	2.0	1.17
Commercial, tetrode	2.9	1.6	0.88
Commercial, power amplifier	40.0	20.0	12.0
Commercial, low-power thyratrons	15.0	6.0	3.5
Commercial, power thyratrons	41.0	15.0	13.0
Commercial, voltage regulator	7.1	0.35	0.13
Power	13.5	10.0	3.8
Power, JAN	9.45	7.0	2.17
Ruggedized	9.6	5.0	3.0
Receiving	3.24	2.0	1.5
Receiving, gas-filled	6.5	3.9	2.7
Receiving, JAN	2.6	1.7	1.1
Receiving, miniature	5.7	3.08	2.1
Receiving, ruggedized	2.0	1.2	0.6
Reliable, single diode	1.49	0.8	0.26
Reliable, double diode, ½	1.37	0.6	0.20
Reliable, double diode, tied	1.87	1.0	0.45
Reliable, tetrode	2.9	1.6	0.88
Reliable, pentode	2.8	1.6	0.79
Reliable, power amplifier	32.0	20.0	6.0
Reliable, thyratron, low power	3.7	2.0	0.25
Reliable, power thyratron	14.3	5.0	3.7
Reliable, klystron	6.00	3.0	1.20
Reliable, fixed magnetron	350.0	150.0	75.00
Reliable, tunable magnetron	5500.0	3000.0	450.0
Reliable, hard tube pulser	43.0	30.0	20.0
Microwave switch	9.0	5.0	2.8
Subminiature, single diode	2.2	1.1	0.96
Subminiature, double diode, ½	1.7	0.85	0.26
Subminiature, double diode, tied	2.21	1.3	0.39
Subminiature, single triode	2.91	1.75	0.53
Voltage regulator	0.68	0.35	0.12

TANTALUM CAPACITORS

- Keep the working voltage at approximately 80 per cent of full rating to contain surges within the full working voltage range.
- Do not permit the time of surge-voltage application to exceed 30 sec every 10 min. Dielectric film forms at any voltage held for any length of time.
- Use only low voltages with slug-type capacitors. Due to the large distance between the anode and cathode, the slug type contains a highly conductive electrolyte to lower the resistance.
- Use the slug type instead of the foil type in non-polar applications where less volume is a consideration.
- Partially form the cathode to ensure reliable operation in abnormal conditions (such as reversal of potential).

CHOPPERS

- If a single chopper is to be used for modulation and demodulation, select a make-before-break chopper to keep at least one end of the amplifier always at ground. Otherwise, trouble will arise, since both output and input are at the same tube socket. If such a chopper jitters or the contacts wear so that it loses its shorting action, the circuit is abruptly disabled by internal oscillation.
- Use two separate choppers, one for modulation and one for demodulation, if gains above 30,000 are necessary.
- Chopper noise may be either electrostatic or electromagnetic. Where noise and amplifier offset are critical, operate the chopper at a frequency other than that of the main power source. Use a chopper whose coil leads conduct out the top of the case for very low noise levels. Connect the chopper ground lead directly to the point where the first amplifier stage cathode bias resistor is grounded. Run this chopper lead close to the grid lead to keep the loop small and free of external magnetic fields.
- Keep in mind that spike noise is occasionally observed in some choppers. It appears as a pulse of noise occurring just as the contacts



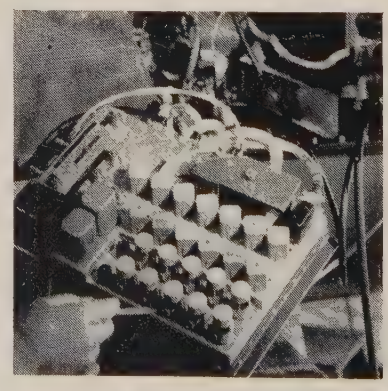
Aircraft flight simulator at Cornell Aeronautical Laboratory puts new aircraft designs through their paces, saving countless dollars of Air Force development costs. Analog computer circuitry can pre-evaluate stability and control characteristics in advance of flight.

Specified for reliability:

Bristol choppers help pre-test tomorrow's aircraft

Finding out just what a new superspeed jet or rocket aircraft will do *before* it leaves the ground—even before it leaves the drawing boards—is the job of the aircraft simulator at Cornell Aeronautical Laboratory, Inc., Buffalo, New York.

This vital equipment, equivalent to a medium size analog computer, employs more than 600 transistors and hundreds of other components connected by more than five miles of wiring . . . among them 46 Bristol Syncroverter* choppers. High reliability, low noise and long life are the qualities that are recommending these choppers to more and more designers of critical circuitry. More than 200 models available. Write for full specifications.



10 Bristol Syncroverter* choppers (foreground) are used in this unit which governs "pilot's" instrument display. 1.25

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American Chain & Cable Company, Inc. ACCO

*T.M. Reg. U.S. Pat. Off.

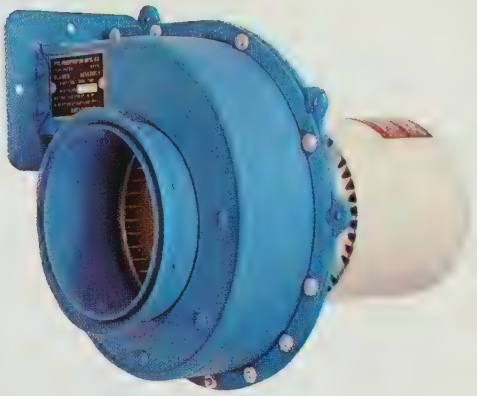
BRISTOL...engineers for precision, builds for reliability

No. 193 on Reader Service Card

No. 167 on Reader Service Card

MOVING AIR IS CHILD'S PLAY

CONTROLLING IT TAKES AN EXPERT



Dexterity is achieved through patience and practice. Our ability to solve the most complex air moving and cooling problems depends partly on these qualities, but mostly on imaginative design, which comes only with experience . . . and maturity. Brochure 102 gives our background. Write for it.

TORRINGTON
MANUFACTURING COMPANY
TORRINGTON CONNECTICUT

break. This is generally caused by a microscopic speck of insulating material between the contacts. The speck sets up a minute static field that is broken by the contacts in the act of separating.

CIRCUIT BREAKERS

- Ambient-temperature variations may change the operating point of thermal breakers so that they either fail to protect against overloads or operate needlessly. At low temperatures, the breaker may not protect if the characteristics of the bimetallic strip are not compatible with the equipment to be protected. At higher temperature, the strip may cause unnecessary circuit interruptions.

- The circuit breaker should work rapidly to protect against short circuits. Allowance must be made for temporary overloads during warm-up.

- Use a series overload trip if the circuit breaker is to serve as both the main switch and overload protective device.

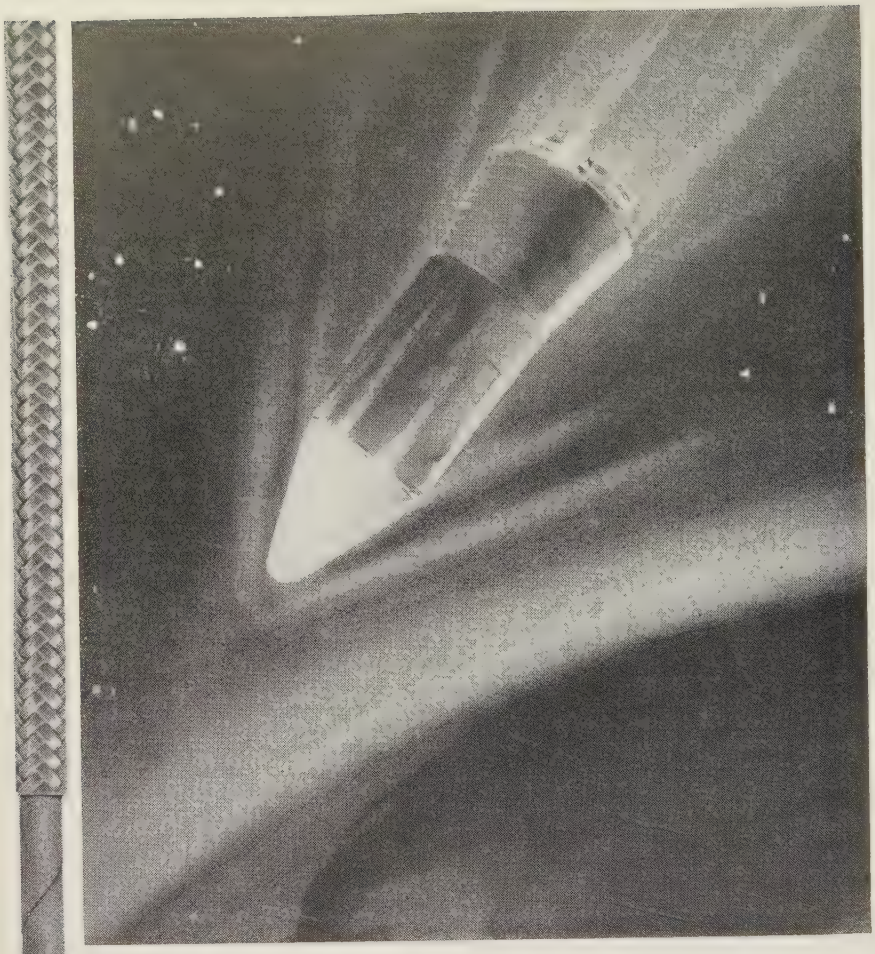
- Use a shunt trip for remote switching. With this type of circuit breaker, interlocks are used that are sensitive to, and whose operation is dependent upon, temperature, pressure, humidity, time, or any other measurable parameter.

MAGNETIC CLUTCHES

- Specify a unit with a life of at least one million cycles at no load, zero speed, room conditions.

- Principal limits to clutch reliability are bearing failures in severe environments. Contamination in spite of bearing shielding is unavoidable. Condensation of moisture from humidity can cause some small reduction in torque, especially on friction-brake surfaces of clutch-break combinations. Compensate for this by conservative performance ratings to allow for the losses. Good internal shielding, rugged plating, and nonoxiding brake surfaces will contribute to proper design for severe environments.

- In designing two-speed systems,



Micatemp Aerospace Wire Resists Nose Cone Heat in Minuteman

Rockbestos Micatemp wire is an ultra-high temperature lead wire that will withstand temperatures up to 2000°F. Because of its ability to carry current at such extreme temperatures, it is used for wiring sub-assemblies in the Minuteman nose cone. Micatemp is also highly resistant to vibration fatigue and radiation.

Developed specifically for missile and satellite wiring, Rockbestos Micatemp wire offers interesting design capabilities for many other military and industrial applications. If you are looking for an ultra-high temperature or radiation resistant wire for your project, be sure to consider Micatemp.

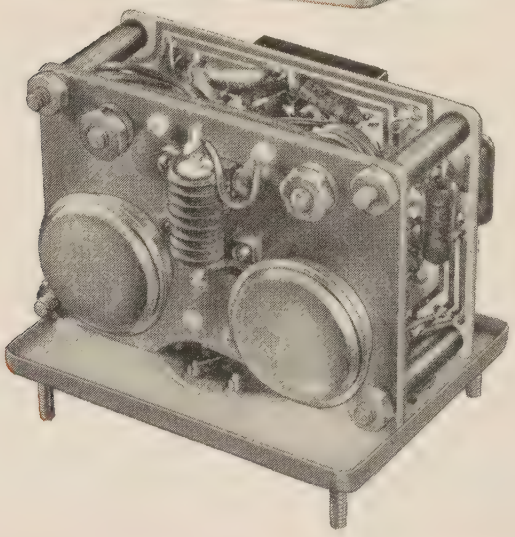
The new Rockbestos Aerospace & Electronic Catalog can help solve your wire and cable problems. Send for your copy today.

ROCKBESTOS WIRE & CABLE CO.

DIVISION OF **CERRO CORPORATION**

MAIN OFFICE AND FACTORY: Nicoll and Canner Streets, New Haven, Conn.

No. 194 on Reader Service Card



INLAND

first with solid state 100-watt d-c amplifier

Inland's new **Model 579.35** d-c amplifier has a high power output of 100 watts when used with low impedance loads requiring direct current. And this completely transistorized amplifier is packaged in a hermetically sealed can only **2½″ x 3 3/16″ x 2½″**.

Designed for use with d-c torquers, in one typical application Model 579.35 provides 65 db power gain between the output of a d-c driver stage and the input terminals of a permanent magnet torque motor. This amplifier has these outstanding performance characteristics:

- The d-c output has magnitude and polarity proportional to the input signal.
- All amplifier circuits use a combination of silicon and germanium transistors (all-silicon models also available).
- Amplifier null and gain are stable and independent of temperature.

Inland also makes a complete line of rotary amplifiers for matched use with Inland's distinctive pancake shape d-c torquers.

A brochure on this new high-power amplifier is available. For your copy and complete data on Inland torquers and amplifiers, write Dept. 212.

TYPICAL SPECIFICATIONS

Maximum Power Output, watts (6 ohm load)	100
Power Gain	4,000,000
Current Gain	200,000
Voltage Gain	15
Frequency Response	DC to 1000 cps
Input Impedance, ohms	50,000
Dimensions, inches	2½ wide 3 3/16 long 2½ high
Operating Temperature Range in °C	minus 50° to plus 50°

INLAND MOTOR

INLAND MOTOR CORPORATION OF VIRGINIA • A SUBSIDIARY OF KOLLMORGEN CORP., NORTHAMPTON, MASS.

No. 195 on Reader Service Card

WOULD YOU INVEST FOUR CENTS TO PUT MILLIONS OF DOLLARS WORTH OF ADDED ENGINEERING KNOW-HOW BEHIND YOUR COMPUTER, APPLIANCE OR COMMUNICATIONS SYSTEM DESIGNS?

If these are your fields of electronics — Teflon* insulated wire and cables must be of prime importance.

Most who know will agree that Brand-Rex has invested more in engineering talent and manufacturing facilities to design and produce Teflon insulated wires and cables than any other company. Result . . . you have at your beck and call (a 4¢ letter will do) a vast dimension of engineering capability. It gives you engineering help that backs up your designs with the wire or cable performance reliability that only unduplicated experience in Teflon insulation can give you. In return, you aren't even under obligation to buy from Brand-Rex.

But again, counting on our broad experience, we think you will. Why?

If the Teflon insulated wire or cable that meets your requirements is not a *standard*, Brand-Rex might well be the only manufacturer in the world that could make it for you economically. If it is a standard, chances are Brand-Rex can supply it to you fastest, right from inventory, from whichever of the three Brand-Rex plants is nearest you. U.L. approvals and military specifications aren't a problem either. Brand-Rex has all applicable U.L. approvals and has geared its line to meet applicable military specifications.

Don't get the idea this is a monopoly situation (FTC take note, please), because there are other people in the business. It's just that Brand-Rex has matched its interest in this type of wire and cable with the biggest investment. And don't get the idea, either, that Brand-Rex will prejudice its insulation recommendations to you because of this extensive Teflon capability, cause it isn't so. Brand-Rex also insulates with vinyl, polyethylene, neoprene and nylon. With the depth of the total Brand-Rex line you can be sure of objectivity.

SPECIFY TURBOTEMP

TEFLON INSULATED WIRE & CABLE

*DuPont registered trade name.

BRAND REX

DIVISION OF

American ENKA Corporation

31 Sudbury Road, Concord, Massachusetts

Telephone: EMerson 9-9630

Vinyl, Teflon, Neoprene, Nylon, Polyethylene Wire and Cable—Electrical Tubing and Sleeving—Rexolite® Microwave Dielectri

NEW! THIS COMPREHENSIVE BROCHURE DESCRIBE AND CHARTS THE ENTIRE TURBOTEMP LINE

PLUS, THE COMPLETE STORY ABOUT HOW THI INSULATION ADVANTAGES OF TEFLON CA HELP YOU DESIGN MORE EFFECTIVELY. **WRITE** FOR YOUR COPY TODAY

No. 196 on Reader Service Card

BRAND REX

TURBOZIP™ military-type vinyl zipper tubing

Now just "zip" it shut... this is the fastest, most economical method of jacketing your own cables. Two types available, both fabricated from Brand-Rex military vinyl compounds . . . Turbozip 40 for low temperature requirements (to —67°C), Turbozip 105 for high temperature applications (continuous operation at 105°C).

For complete information and samples, or if you wish, technical assistance in selecting the right insulation for your application, write or call

BRAND REX
DIVISION OF
American ENKA Corporation
SUDBURY ROAD, CONCORD, MASSACHUSETTS
TELEPHONE, EMERSON 9-9630

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gearing must not be driven backward. Since this possibility does not normally occur, it may be overlooked by the gear-train designer.

- The major difficulty in high-speed low line frequency applications is dither resulting from pulsating of the rectified current. Coil inductance will provide some smoothing.
- Insulate the magnetic path from the bearings to avoid electrolytic corrosion from voltages generated by the balls rotating in a magnetic field.
- Do not use crown-tooth clutches for slip applications.

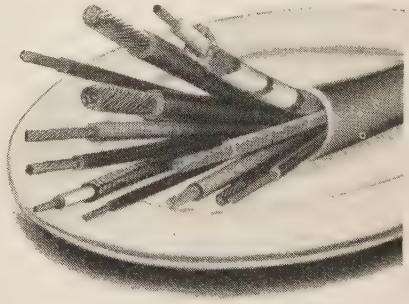
COILS

- If circuit stability is important (as in an oscillator or discriminator) because small changes in inductance or capacitance cause large or important changes in operation, use as large a capacitance as practical while maintaining a reasonable inductance.
- If slight changes in inductance and capacitance cause large changes in frequency or other parameters, all components must be selected for best stability. The mechanical assembly must be rigid, and hermetic sealing should be used.
- Avoid long leads. If the coil is attached to its circuit by long leads, the effective distributed capacitance will be increased by the capacitance of the hot lead to ground. The lead capacitance must be added to the distributed capacitance of the coil to determine the total effective coil capacitance.

STANDARD CONNECTORS

- For components that will be exposed to moisture, use AN connectors in the E class (environment-resisting).
- Above 100 mc, the match between RF connectors and cables is critical.
- Use connectors with a pin insertion of ⅛ in. or more.
- The best spring material for current-carrying parts is copper-beryllium (heat-treated to Rockwell C30-35).
- Large connectors, or connectors with many contact pins, must have guide pins to insure axial alignment

CABLES à la carte



MENU

Tinned or Silver-plated Copper Conductors Solid or Stranded

Insulation of TFE or 100 FEP Teflon; Silicone Rubber

Jackets of Nylon, TFE or 100 FEP Teflon (tape-wrapped or extruded) Silicone Rubber or Fiberglass

Multiple Conductors and Twisted Pairs

Braided Metal Shielding

An engineer can't always design around a stock cable. That's why we make up special cable constructions exactly to fit your needs—from such a variety of components as is suggested by the above "menu." Cables "a la carte" are economical in the long run—because they effect big savings in your wiring and assembly costs. Let us quote you on a special FLEXLEAD cable for your next application. Phone, write or wire!

MARKEL SINCE 1922
FLEXLEAD®

1 SOURCE for EXCELLENCE
Insulating Tubings and Sleevings
High Temperature Wire and Cable

L. FRANK MARKEL & SONS
NORRISTOWN, PENNSYLVANIA

No. 198 on Reader Service Card

of the receptacle and plug. Polarize the guide pins for proper orientation of the connector assembly.

✔ Avoid connectors with laminated inserts; moisture can seep between the layers.

✔ Do not use inserts with fillers of nylon or glass fiber. They are subject to cold flow and will loosen in the shell.

✔ Do not place connectors near temperature-shock zones—temperature shock tends to crack and delaminate insulators and radiant heat causes warping, flow, melting, or sublimation. In addition, high temperature accelerates oxidation and causes plating to deteriorate.

✔ Use a rubber ring between insert and shell or a resilient insert to provide some degree of shock mounting. Vibration may crack the insert material of an electrical connector, break wires at the solder joints, or cause the mating parts to separate.

✔ To prevent flashover and corona effect, use pressure-sealing, resilient rubber seals, grommets, and O-rings for altitudes above 100,000 ft. Glass-to-metal bonds are best.

DIODES

✔ Overload currents must be considered when germanium and silicon rectifiers are used—the effective internal resistance of these rectifiers is low and does not limit the circuit current. Also, their high current density results in concentrated heating.

✔ For best reliability, the junction temperature in germanium diodes must not exceed 90 deg C. Silicon diode junctions must not exceed 180 deg C.

✔ The AC circuit of a DC series inductor rectifier must be opened first to prevent inductive kick when the DC series inductor circuit is broken.

✔ On all single-phase rectifier circuits with capactive or battery loads, decrease the resistance-load current rating to 0.8.

✔ If a new circuit is being tried for the first time, apply 10 per cent of the rated input alternating current and check all DC voltages before bringing the AC voltage up to normal.

✔ Mount rectifiers in the coolest available spot.

✔ Mount rectifiers on the top of a chassis for better heat radiation and air circulation.

✔ Solder rectifiers quickly. Use a heat sink and do not overheat. A cool iron, applied long enough to solder, will do more damage than a quick touch with a hot iron. Take care when using commercial irons, since it is possible to cause leakage current that burns out some types of diodes.

✔ Paint is not insulation. Do not depend on the paint coating as an insulator.

✔ Always use a torque wrench to tighten stud-mounted diodes and transistors. *Do not* overtorque.

✔ Be sure of polarity. Connecting a polarized electrolytic capacitor

Bendix®
ELECTRICAL
CONNECTORS
delivered in
48 hours or less!

We can fill your order faster . . . meet MIL specifications . . . yet our charges will be competitive with your slower supply sources.

Airwork is a factory-authorized Bendix jobber, supplying all popular types of connectors, including the latest Pygmy crimped contact types. Call Dick Read, OEM Division, at TUxedo 7-8253 for a quotation.

Airwork
Airwork CORPORATION
5245 N.W. 36th Street
MIAMI SPRINGS, FLORIDA

PYGMY®

No. 199 on Reader Service Card

To thread a needle in unmanned flight...

required Motorola systems ingenuity

NAVIGATION with "needle's eye" precision is achieved by Motorola RDI. Synergistic combinations of Radio, Doppler, and Inertial sensory data into one integrated system exceed the sum of the capabilities of each. Ranging hundreds of miles from their ground-anchored reference, these R+D, R+I and R+D+I combinations provide targeting accuracy...immunity to interference...resistance to detection. Unique combinations of these techniques have been proven in applications requiring real-time, position-fixing and space vehicle-guidance. These Motorola systems originally were designed for missile guidance and surveillance drone navigation...they now provide reliable solutions to a broad range of problems requiring continuous, current, and extremely accurate control data never before attained in a dynamic environment. Sensory synergism is another demonstration of Motorola's systems ingenuity. Classified details of these programs are available to those with an established need to know.

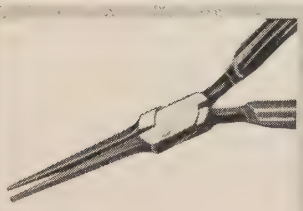
Military Electronics Division **MOTOROLA**

All qualified applicants will receive consideration for employment without regard for race, creed, color, or national origin

CHICAGO 51, Illinois, 1450 North Cicero Avenue
SCOTTSDALE, Arizona, 8201 East Mc Dowell Road
RIVERSIDE, California, 8330 Indiana Avenue

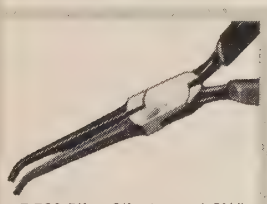
No. 200 on Reader Service Card

Snap-on PRECISION PLIERS and CUTTERS for Electronic Assembly

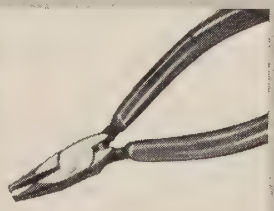


E-701 Plier. Slim-tapered 2 3/16" jaw. Non-serrated 1/16" tip.
E-703 Plier with serrated tips.

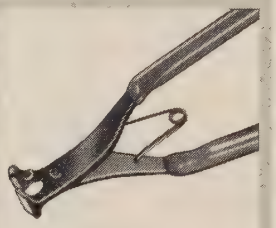
- Selected alloy steels with jaws specially heat-treated for maximum strength
- Snap-on pliers are heat-treated clear through — not surface-hardened only.
- Broached and ground joint surfaces for smooth, snug fit . . . eliminate binding.
- Drilled and reamed rivet holes for easy operation.
- Controlled riveting for accurate alignment and mating of jaw tips.



E-702 Plier. Slim-tapered 2 1/4" bent jaws. Non-serrated 1/16" tips.
E-704 Plier with serrated tips.

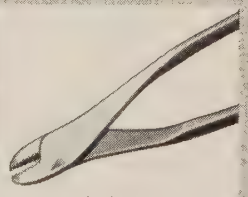


E-705 End Cutter. 4 1/2" long. Jaws 3/4" long. 1/8" flush-cutting tip blades.

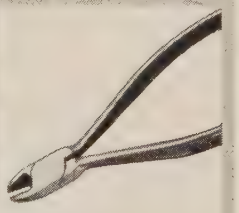


E-706 End Nipper. 6 1/8" long. Flush-cutting blades 7/16" wide.

- Cutter blades are hand-filed for accurate meshing.
- Overlapping cutting edges shear better, last longer.
- Models available with plastic-coated handles, plastic jaw inserts.
- Many other sizes and types available.



No. 5 Gripping Plier. 4 1/2" long. Thin jaws with fine teeth.

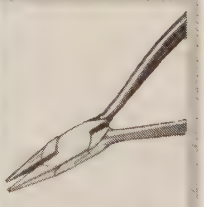


No. 184 Diagonal Cutter. 4 1/4" long. 13/32" jaw length.

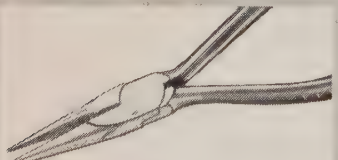
No. 184D Cutter. 4 1/4" long. Semi-flush-cutting action.
No. 184DD Cutter. Full flush-cutting action.

No. 85 Diagonal Cutter. 4 7/8" long. 5/16" jaw.

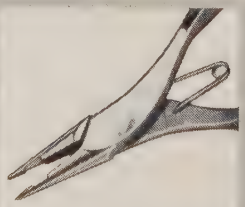
No. 85L Long-Nose Diagonal Cutter. 5 1/16" long, 3/4" jaws.



No. 94 Needle Nose Plier. 4 1/2" long. 27/32" serrated jaws.



Needle Nose Pliers with serrated jaws.
No. 095. 5 3/16" long. 17/32" jaws.
No. 95. 6" long. 1 1/16" jaws.
No. 096. 6 3/4" long. 2 1/32" jaws.



No. 951S Gripper-Cutter. 5 1/2" long. 1 7/8" jaws with cutter 7/32" from tip.

Write for new Bulletin 173A listing wide range of small tools particularly suited for electronic assembly.

FOR ALL INDUSTRY
SNAP-ON TOOLS
8080-L 28th AVENUE • KENOSHA, WISCONSIN

backward will almost certainly damage a rectifier.

SELENIUM DIODES

- Design equipment so that the cooling air passes over the diodes before the other components.
- Best design requires an exhaust-type circulatory system, where the fan or blower exhausts the hot air from the power supply, and cool air is drawn in (over the diodes) by the reduction in pressure.
- Never cool rectifier stacks by direct blowing against the stack by a propeller-type fan. Air flow in front of this type of fan is very nonuniform.

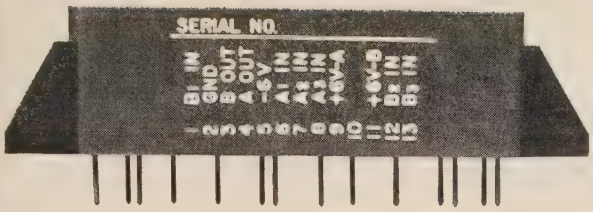
ZENER DIODES

- Zener diodes, when biased in the reverse direction, can be used as voltage regulators or reference elements. They have a longer life than other types of reference elements and do not deteriorate under storage.
- The maximum permissible diode current is limited by the temperature rise of the junction and by the heat sink. Thus, a Zener diode is limited as a voltage-regulator element only by its rated current-handling capabilities.
- For very close tolerance silicon regulator assemblies, connect lower voltage units in series. The power dissipation per unit in a series combination is inversely proportional to the number of units in series. Life expectancy doubles with every 10 deg C drop in junction temperature.
- Zener diodes require on the order of 30 per cent or more of their rated current for optimum regulation and cannot be derated as much as other components. Be sure to heat-sink these components properly.

ELECTRON TUBES

- Choose types for circuits that do not require hand-selection.
- Used forced air cooling if heat sink, conduction, and other heat-transfer characteristics of mounting and chassis are not enough. Do not take chances with marginal cases. Bulb temperatures can be deter-

No. 201 on Reader Service Card



In less time than it takes light to cross this room, a new product, **DELCO'S NEW** high speed **10 MC** silicon modules, could: (1) correct the course of a missile in flight; (2) make it possible for sonar pickups to track and compute the position of targets with microsecond accuracy; and (3) handle any number of other airborne guidance and control functions that previous modules—due to low speed or environmental or performance limitations—could not handle. Delco Radio's 10mc modules, with a maximum gate-switch speed of 40 nanoseconds, convert data 100 times faster—even under the most extreme environmental conditions.

These **SILICON** modules come epoxy encapsulated, and operate over a temperature range of −55°C to +100°C. And these same reliable **DIGITAL** circuits are available packaged on plug-in circuit cards. These Delco **MODULES** are environmentally proved to: **SHOCK**, 1,000G's in all planes. **VIBRATION**, 15G's at 10 to 2,000 cps. **HUMIDITY**, 95% at max. temp. **STORAGE AND STERILIZATION TEMP.** −65°C to +125°C. **ACCELERATION**, 20G's. Designed for systems using from one module to 100,000, and the module's rated performance considers the problems of interconnection. Data sheets are available. Just write or call our Military Sales Department.

Physicists and electronics engineers: Join Delco Radio's search for new and better products through Solid State Physics.

PIONEERING ELECTRONIC PRODUCTS THROUGH SOLID STATE PHYSICS

Division of General Motors • Kokomo, Indiana

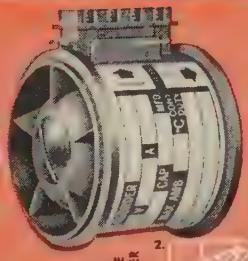
DELCO RADIO

AXIMAX MINIATURE 400CPS FANS

AXIMAX 1

12 to 23 CFM
11,400 to
22,500 RPM

1⅝" x 1¾"
4 OZS.



- Extremely compact and lightweight—1½" x 1¾", 4 ozs.
- 115 or 200 VAC, 1 ø or 3 ø, 400 cps.
- Airflow reversible.
- Built to Military Specifications.

AXIMAX 2

24 to 60 CFM
8,000 to
20,000 RPM

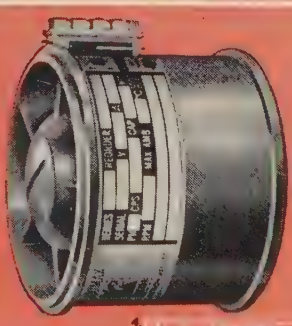
1⅝" x 2"
4½ OZS.

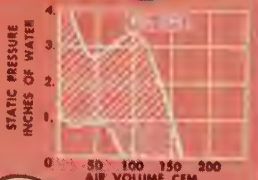
- Size: 2" x 1½". Weight: 4½ ozs.
- 115 or 200 VAC. 320 through 1600 cps. 1 ø or 3 ø
- High altitude (Altivar)® and high density designs available.
- Airflow reversible.
- Built to Military Specifications.

AXIMAX 3

70 to 165 CFM
9,000 to
22,000 RPM

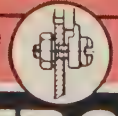
2⅜" x 3¼"
14 OZS.





- Size: 3¼" x 2⅜". Weight: 14 ozs.
- 115 or 200 VAC. 400 and other cps. 1 ø or 3 ø.
- High altitude (Altivar)® and high density designs available.
- Airflow reversible.
- Built to Military Specifications.

Appropriate cam-locking mounting clamps are available from Rotron for servo-mount Aximax fans.



Write for Complete Technical Details, or Submit Your Cooling Problems for Recommendations...

ROTRON

ROTRON MANUFACTURING CO., INC.
WOODSTOCK, NEW YORK

mined with reasonable accuracy by painting the bulb with temperature-indicating paints that have closely controlled melting points. ("Tempilaq" is a trade name of one of these paints.) Bulb puncture is aggravated by high temperatures.

- For increased reliability, keep the envelope temperature of small receiving-type power tubes below 175 deg C.
- With a JAN-type shield, all common tubes operate at higher than their base-bulb temperatures; with a heat-conducting shield, such as the Mil-S-93722 Type-B, they operate at lower temperatures.
- For reliability, avoid designs where tubes are subjected to all maximum ratings simultaneously.
- Use an indirectly heated cathode for longer life and higher reliability.
- For improved thyratron performance, connect the cathode at the center tap of the filament transformer and phase the filament voltage in quadrature 90 deg with respect to the mode supply.
- Electron tubes normally cannot stand more than 10 g of vibration in the 10 to 2000 cps range.
- Microphonics are greatest when tubes are normal to the direction of vibration.
- To prevent uneven distribution of voltage, use a parallel instead of a series hook-up of filaments.
- Apply filament voltage in discrete steps until rated voltage is attained. This will minimize filament burnout.
- To prevent lead breakage, use Teflon buttons on subminiature tube leads.

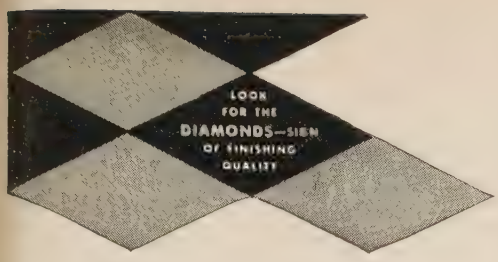
GYROS

- Drift under vibration is directly proportional to the level of vibration and is worst when the direction of vibration is parallel to the spin reference axis of the gyro. A direction of vibration along the output axis of the gyro is least detrimental to gyro performance.
- Resonance occurs under vibration at from 5 to 2000 cps—the fundamental and harmonics of the wheel fork.

SOLDER JOINTS

- Solder intricate, complex connections with an iron or gun.

No. 203 on Reader Service Card

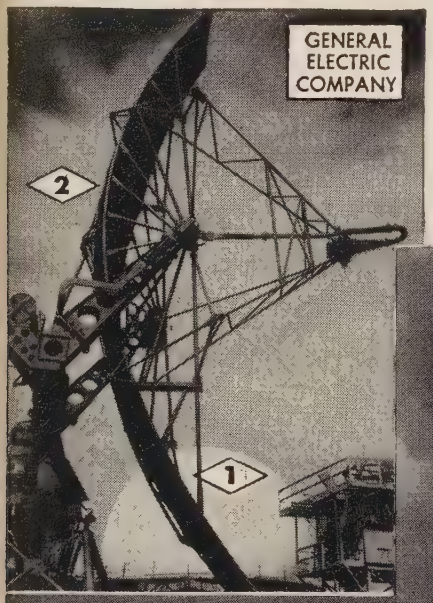


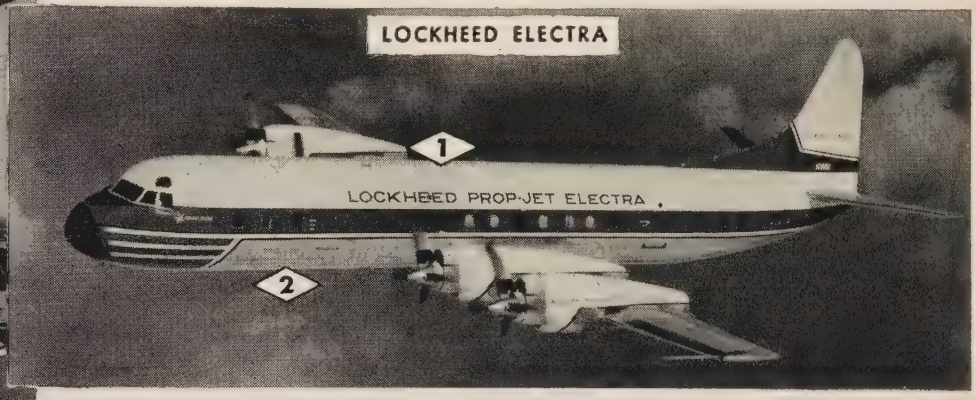
for a superior paint base on light metals

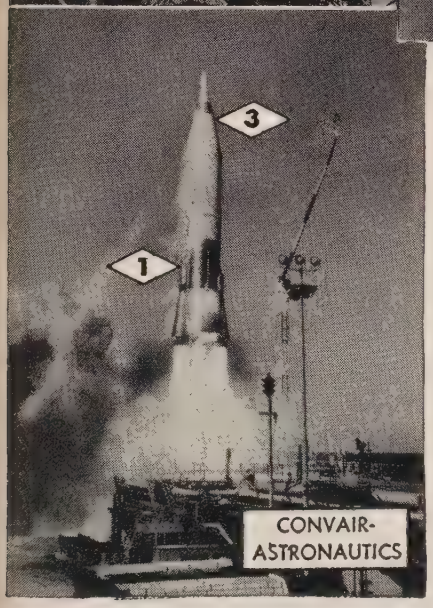
you need IRIDITE®

PROCESS ENGINEERED CHROMATE CONVERSION COATINGS

1. Iridite protects against high altitude weather extremes and against corrosion by hydrocarbon fuels, such as gasoline and kerosene.
2. Iridite provides a highly protective non-porous paint base.
3. Iridite protects against corrosive storage conditions.







And, Iridite gives you these additional advantages:

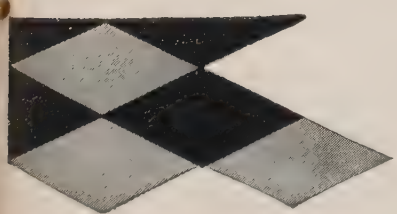
ON ALUMINUM—needs only normal pre-cleaning. Film withstands cold forming or bending. Easily heliarc welded. Unusually low electrical resistance. Clear, yellow or dye-colored finishees.

ON MAGNESIUM—short immersion, room temperature solution, no electrical equipment. Corrosion protection relatively unaffected by high drying temperatures. Applicable to all alloys. Low electrical resistance. Color ranges from light gray to dark brown.

IRIDITE—a specialized line of chromate conversion coatings for non-ferrous metals. Easily applied at room temperatures with short immersion, manually or with automatic equipment. Forms a thin film which becomes an integral part of the metal. Cannot chip, flake or peel; special equipment, exhaust systems or highly trained personnel not required.

Iridite is approved under government and industrial specifications.

For complete information on Iridite, contact your Allied Field Engineer. He's listed under "Plating Supplies" in the yellow pages. Or, write for FREE TECHNICAL DATA FILES.



Allied Research Products, Inc.

4004-06 EAST MONUMENT STREET • BALTIMORE 5, MARYLAND

Affiliated operations in principal countries

No. 204 on Reader Service Card

- Use induction soldering for small, intricate pieces of light-gage metal that might oxidize excessively if heated by a flame.
- For soldering to silvered surfaces, use a silver-bearing solder.
- For soldering metal to glass, use the alloys formed by indium with tin, lead, or silver. They have relatively low melting points and will wet glass.
- Extend the tinning on a wire only far enough to take full advantage of the depth of the terminal or receptacle. Tinning or solder on wires outside the receptacle where flexing may occur causes stiffness and eventual breakage.
- To inhibit formation of grey tin in tin-lead solders at extremely low temperatures, use a minimum of 0.1 per cent bismuth and 0.1 per cent antimony.
- Do not use lead-antimony solder with vibrating loads.
- Do not use 20 per cent lead—80 per cent bismuth solder where both vibration and high temperature are expected.
- For printed circuits, strengthen solder joints by flaring a portion of the lead included in the solder fillet.
- Use resistance soldering for uniform solder connections.
- For 500 deg F operation, the following platings will provide good solderability and resistance to metallic diffusion: gold plate over nickel plate, rhodium plate over silver plate, and nickel plate over copper base metal. Gold plate over silver plate and silver plate over copper base metal are not satisfactory for 500 deg F operation.
- Solder alloy of 1.5 per cent silver per QQ-S-571 has strength and corrosion resistance to withstand 500 deg F.
- Remove flux residue (volatized and nonvolatized) from high impedance circuits.
- Soldered connections, when exposed to test environments (500 deg F for 200 hr, salt spray for 50 hr, humidity for 10 days and thermal

Transistor / Filament
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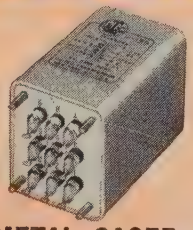
TRANSFORMERS
400 CYCLE TYPES

UTC
PIONEERS IN MINIATURIZATION

Smallest METAL CASED

Immediate Delivery
FROM STOCK



METAL CASED

MOLDED

THESE units are designed for a wide variety of Transistor/Filament circuit applications. Conservative design plus rugged mechanical construction assure high reliability under the most severe environmental conditions. Power ratings are: Primary 28/115V, 380/1000 cycles; Secondaries 6.3V up to 25 amps; Test voltages up to 2500V RMS.

UNITED TRANSFORMER CORPORATION
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EXPORT DIVISION:
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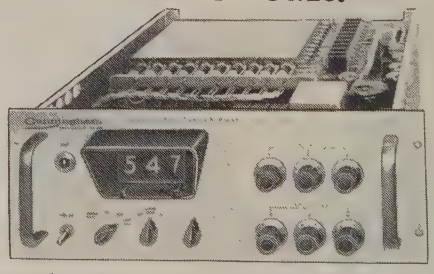
WRITE FOR LATEST CATALOG

No. 205 on Reader Service Card

This 600-Circuit Crossbar Scanner Provides Complete Program Flexibility, Random Access, Near-Ideal Switching, and Over 20 Million Operations Per Circuit.



We believe that the extraordinary command/control flexibility of this unique* Crossbar Scanner will compel the alert systems logician to investigate it minutely. To further stimulate that compulsion, we mention its clear-cut superiority to any other passive switching device. Bulletins 6010 and 60-117 are authoritative, explicit, and applications-oriented.

*Use of this much-abused adjective is, in this case, justified by exclusive U.S. and Foreign Patents.

Cunningham
ESTABLISHED 1838
SOPHISTICATED SWITCHING SYSTEMS
BOX 516, ROCHESTER 2, NEW YORK

Plant & Offices:
Honeoye Falls, N. Y.
Phone: Honeoye Falls 485
TWX RO 572-U

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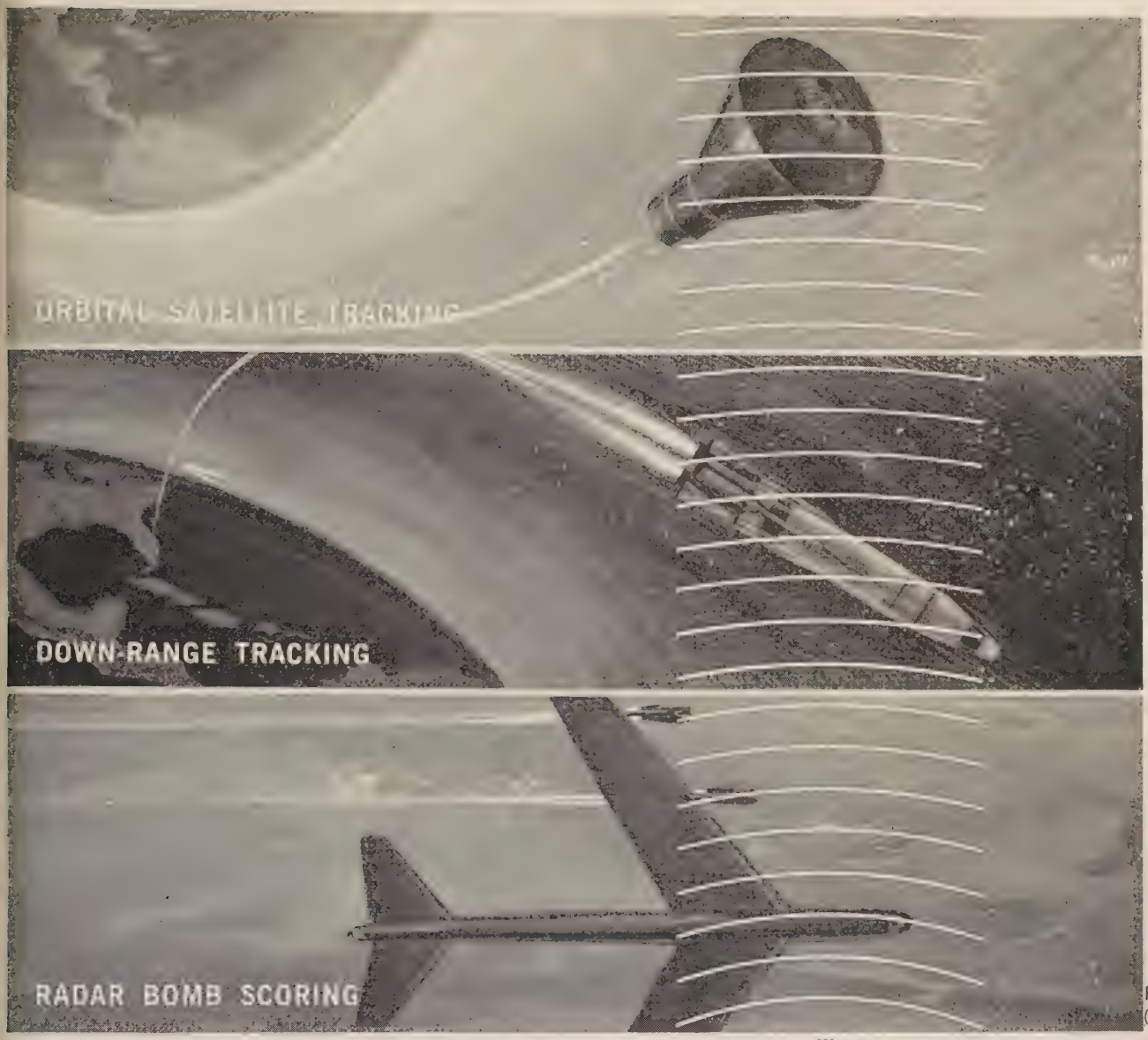


more than 15 years of

RADAR *by* Reeves

THERE'S NO SUBSTITUTE FOR EXPERIENCE

Orbital Satellite Tracking — Discoverer, Midas, Mercury — Over three years of proven field experience in all aspects of satellite tracking.

Down-Range Tracking — Reeves equipment, installed in the early days of Canaveral and White Sands, is still functioning with proven accuracy after nine years of continuous use.

Radar Bomb Scoring — Fifteen years of proven experience in the design, installation, and servicing of complex radar equipment for the scoring of simulated bombing runs.

Whatever your radar requirements may be, Reeves has technical, production, and field-proven experience to meet your requirements.

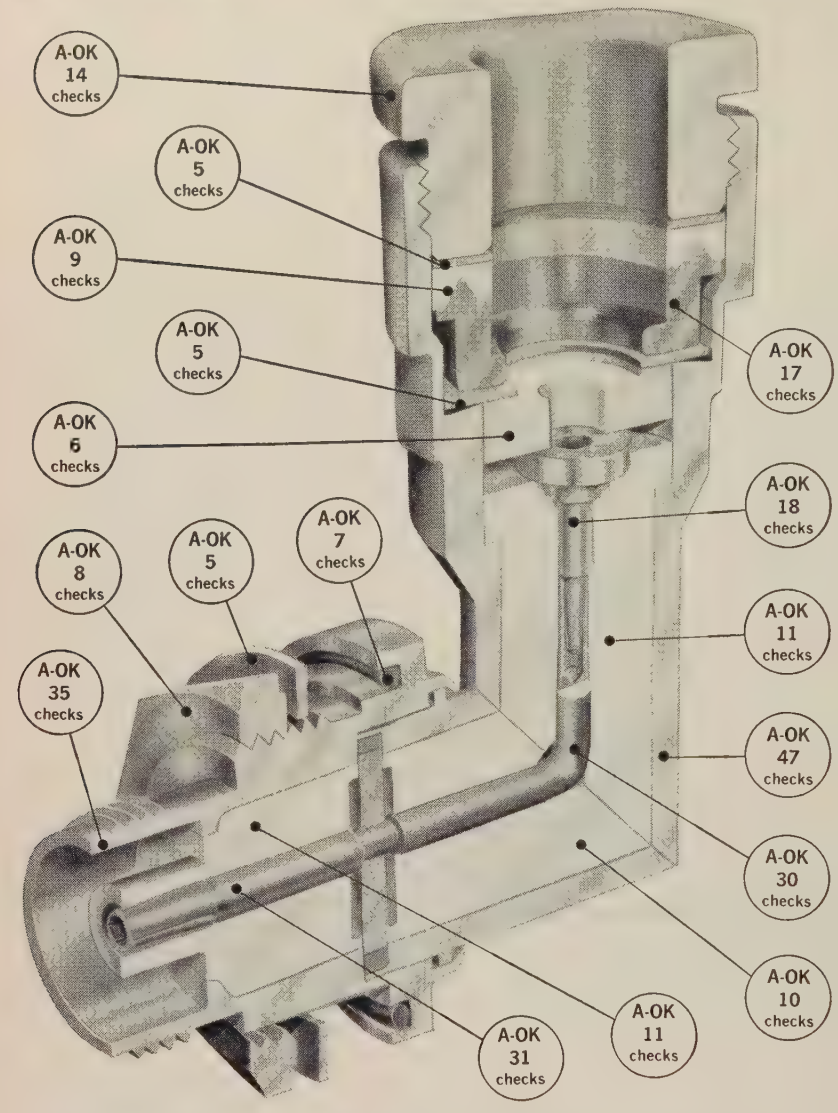
REEVES INSTRUMENT CORPORATION

A Subsidiary of Dynamics Corporation of America • Roosevelt Field, Garden City, New York

Qualified engineers seeking rewarding opportunities in these advan.ed fields are invited to get in touch with us.

8RV61

A-OK···273 TIMES!

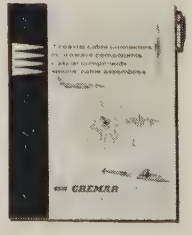


Gremar RF Connectors must pass an average of 273 quality checks before they're passed on to you.

Gremar connectors stand out in reliability because they stand up to the stiffest quality control checks in the industry. From selection of materials to final assembly, every component part must pass the "All O.K." checkout scores of times before we're willing to stamp "Gremar" on the connector. *This is why our connectors are specified in every major defense program in the country!*

RELIABILITY PLUS DELIVERY

If you specify RF connectors with critical reliability requirements Gremar can help you. If it's a *standard* it's probably in stock. If it's a *special* it *may* be in stock — if not, we're geared to make it up fast! If it's a new design we can engineer it and build it in our model shop — fast! Gremar's 58 page Quality Control Manual details scores of quality control checks that insure extraordinary reliability and performance in our connectors.



NEW TIME-SAVING MANUAL

If you specify or purchase RF Connectors, send for the most concise, conveniently organized listing available in the field.

RELIABILITY THROUGH QUALITY CONTROL

GREMAR

MANUFACTURING COMPANY, INC. • WAKEFIELD, MASS. • Tel. 245-4580

cycling from —80 to 500 deg F) show no corrosion. Mechanical properties are somewhat weakened, depending on the test temperature and materials used.

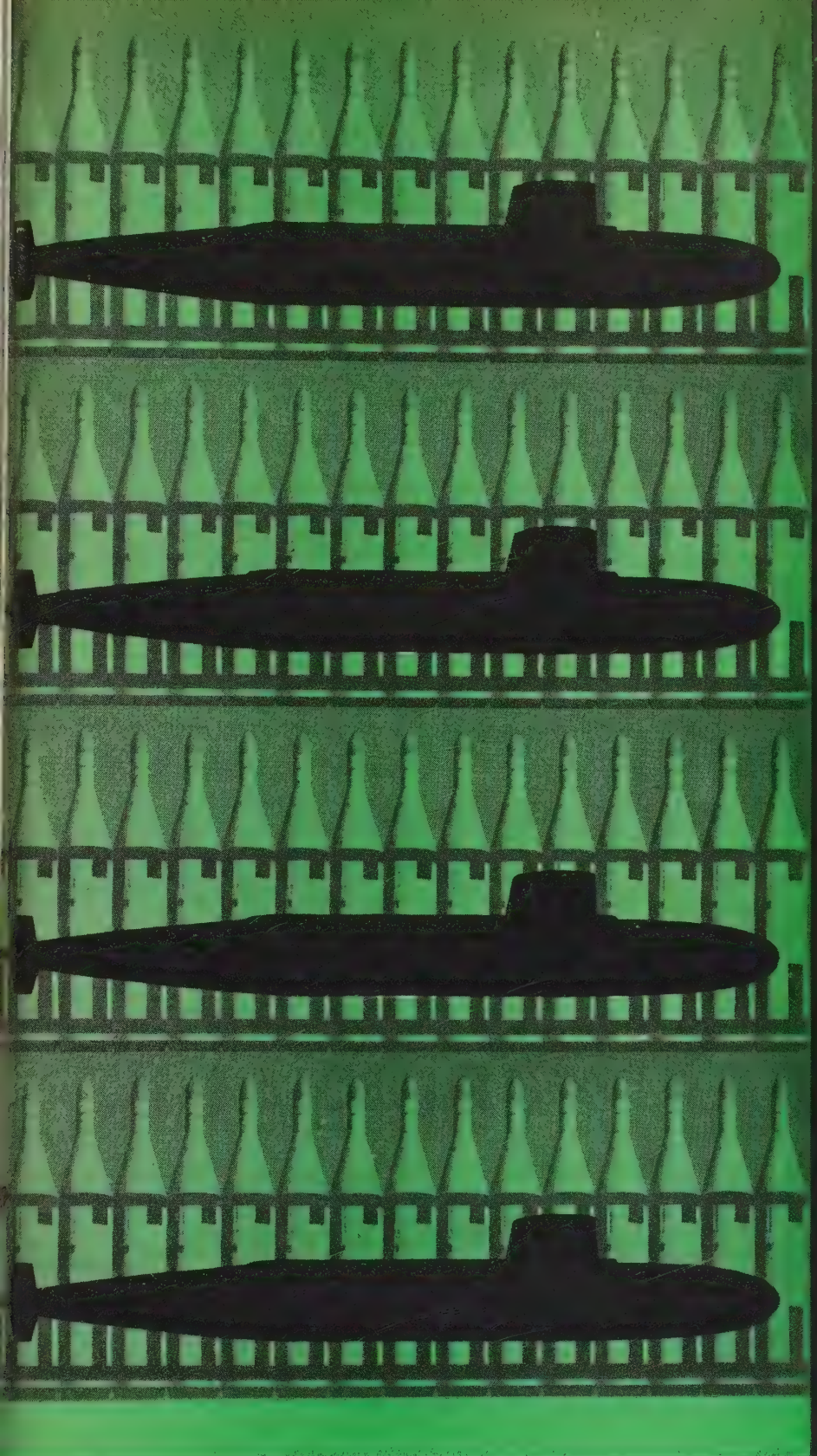
LAMPS

- Lamps are more reliable at lower voltages.
- Replace the six-volt (type 328) filament lamp after 1000 hr of service.
- Age 28 V (type 327) filament lamps for 50 hr. They can then be used to failure without periodic replacement, as the failure rate remains constant.
- Use a series resistor with lamps of about one-eighth the nominal hot-lamp resistance (nominal voltage divided by nominal current.)
- If current surges are more than 15 times normal current, do not place lamps in parallel with inductive loads such as relay coils.

METERS

- To measure circuit conditions with reasonable accuracy, energy taken by the meter must be less than one per cent of the total circuit energy.
- Current-measuring instruments have a drop of less than 50 mv for DC instruments and are used in circuits of over five volts. Frequently, better results will be gotten in test work with an ammeter of higher range and lower resistance, even though the reading is well down the scale.
- Use Mil-M-10304A instruments if extreme shock and vibration will be met.
- Stiff connections to the meter terminals transfer vibrations. This can be avoided by using flexible leads (stranded cable or thin strip) for heavy current connections.
- Do not use a DC meter to measure pulsed DC unless the thermal capacity of the meter will handle the thermal loss produced. (Assume the maximum allowable thermal loss in watts in the meter as twice the full-scale loss under normal conditions of pure DC.)
- Select ranges where normal operation will be in the upper half of the scale—around three-quarters scale for best results, except in the instances referred to above.

No. 208 on Reader Service Card



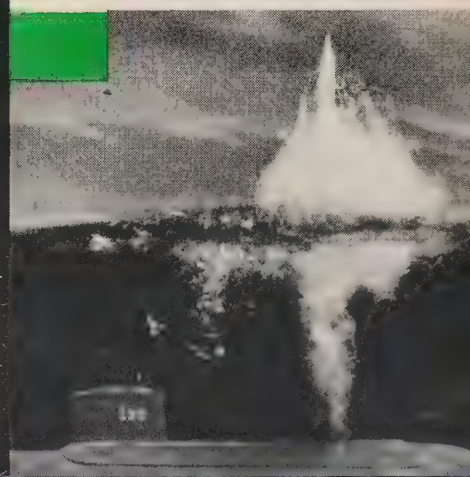
Avco and Polaris

Now at sea—or soon to be—are t nuclear submarines *George Washingto Patrick Henry, Ethan Allen* and *Robe E. Lee.*

Carried aboard such submarines a sixteen Polaris missiles. Their critic arming and fuzing system was man factured by Avco's Electronics ar Ordnance Division.

100% successful in all flight tests date, the tactical units were ready f delivery only twenty-two months aft the start of development. This is t record of the U. S. Navy's Special Pro ects Office, the U. S. Naval Ordnan Laboratory, and Avco's Electroni and Ordnance Division on the Polar arming and fuzing system.

Detonation at the right time and pla is the kind of engineering and produ tion problem that Avco's Electroni and Ordnance Division is well qualifie to solve. If you would like more info mation about Avco's experience ar capabilities in this, and other relate fields in ordnance, write: Director Marketing, Ordnance Operation, Ele tronics and Ordnance Division, Avc Corporation, Richmond, Indiana.



Opportunities for electronic engineers (EEs) in communications, infrared, radar, optics, reliability. Send résumés to: Dept. FP-1 Industrial Relations, Avco Corporation, Electronics and Ordnance Division, Cincinnati 41, Ohio.

Avco // ELECTRONICS AND ORDNANCE DIVISION

No. 209 on Reader Service Card

BULOVA
HIGH FREQUENCY
INDUCTANCE
SUBSTITUTION BOX

Whatever the "variation" you need, the new Bulova inductance substitution box provides the precise measure with three decades of inductance ranging from 0.1 to 111 millihenries.

The Bulova SB-100 uses gold contact subminiature switches to permit low stray capacity and excellent low level contact. Maximum distributed capacity of any selected inductance is less than 20 picofarads, and the maximum useful frequency is in excess of 2 mc. The fully encapsulated coils allow the unit to be used in environmental chambers with a minute inductance change, (approx. +100 ppm/°C).

The use of direct current up to 50 milliamperes without appreciable change in inductance is permitted. The accuracy of the instrument is ±1% true inductance at 1 volt and 25 ± 10°C. Its zero setting residual inductance is 0.5 microhenry.

This new high frequency inductance substitution box is only one of many recent advances made by Bulova Electronics. For information on these specific units, or on how Bulova experience in mastering component and system reliability can help you, write Department 2257, Bulova Watch Company, Inc., Electronics Division, 61-10 Woodside Avenue, Woodside, N.Y.

BULOVA
ELECTRONICS
DIVISION

No. 210 on Reader Service Card

Determine the effect of any meter used on the circuit. Calculate accurately until it is clear that the effect is negligible; if the effect is not negligible, know what it is.

MOTORS

Motors are usually designed for a 104 deg F ambient, with a temperature rise of 108 deg F for Class A insulation and 144 deg F for Class B. When ambient temperature is higher than 104 deg F, the motor rating must be reduced.

Heat-removal data are particularly important in selecting a motor. In general, there are no special standards on safe temperature rise, except the requirement of adequate life. The motor manufacturer confines his temperature rise to what he considers a safe value compatible with the limits of the insulation and lubrication systems.

The two principal design features limiting life of a motor are insulation and bearing lubrication.

POTENTIOMETERS

The ratio of the potentiometer resistance to the lead resistance should be 10 or more.

Several methods of load compensation may be used:

- Introduce a slight nonlinearity in the potentiometer characteristic;
- Pad resistors across tap points;
- Use isolation amplifiers;
- Load two pots similarly when they are balancing against one another;
- Restrict the range by placing resistors in series with each of the fixed terminals of the potentiometers.

The effects of external vibrations can be minimized by appropriate contact-spring design and by using axial spring-loading of ball bearings to eliminate bearing play.

Multiturn potentiometers give better accuracies and resolution than single-turn units.

Single-turn potentiometers are less adversely affected by high frequencies. A multiturn unit sometimes produces phase shifts and quadrature voltages under high frequencies.

Potentiometers withstand longi-

DEUTSCH
CONNECTORS

24 Hour Delivery
COAST-TO-COAST

- **DM Series**—push-pull, meets Mil-C-26482
- **DS Series**—push-pull, insertable, removable, crimp contacts
- **DTK Series**—bayonet lock, meets or exceeds applicable requirements of Mil-C-0026482A
- **DRS Series**—rectangular rack and panel, advanced application performance
- **DC Series**—push-pull, environmental, crimp-type RF connector
- **DM and DH Hermetics**—glass to metal seals, leak proof glass to metal seals

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It's Bonded
Every one of these hermetic connectors has the Deutsch Seal... a glass-to-metal bond that guarantees you leakproof performance. The unique compression glass insert is molded as one solid piece, with steel contacts fused in and numbers imbedded in the glass for quick identification. Every year is a vintage year at Deutsch because each hermetic receptacle is manufactured under quality control procedures that have set new standards in the industry. For more information on the connector with bonded performance, contact your local Deutschman or write for Data File E-12
DEUTSCH
Electronic Components Division
Municipal Airport • Banning, Calif.

ADVANCED SPECIFICATION MINIATURE ELECTRICAL CONNECTORS

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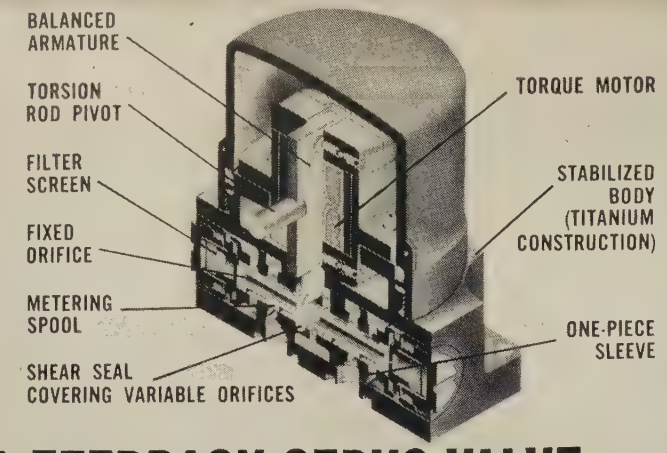


A FEEDBACK SERVO VALVE WITHOUT SPRINGS OR LEVERS

- Unity coupled Hydromechanical Feedback
- High Null Accuracy
- Only 2 moving parts
- Large, full opening, shear-seal orifices

This two-stage, four-way flow control valve is the only one available that provides true positional feedback without springs or levers. The first stage consists of an electrical torque motor and "shear-seal" orifice hydraulic amplifier, while the second or control stage is made up of an accurately matched spool and sleeve arrangement.

Hydromechanical unity feedback relates spool position to torque motor armature position and also nulls out effects of orifice variations due to supply pressure and temperature fluctuations. Flow force reactions are thus substantially reduced and hydraulic centering of pilot position is feasible without spring hysteresis and null shift. Large orifices prevent clogging and silting and high shear forces permit efficient operation even with highly contaminated fluids. Final null adjustments are made electrically by a balancing control at amplifier output stage.

TYPICAL CHARACTERISTICS

	Medium Flow (#6103-#6106)	High Flow (#6104)
Rated flow	to 7.5 gpm at 3000 psi valve pressure drop	to 18.0 gpm at 3000 psi valve pressure drop
Hysteresis	3% maximum total rated current	3% maximum total rated current
Supply pressure	300 to 3000 psi	300 to 4000 psi
Proof pressure	4500 psi pressure port 3000 psi return port	6000 psi pressure port 3000 psi return port
Pressure gain	First stage—500 psi per ma minimum with 3000 psi supply	First stage—500 psi per ma minimum with 3000 psi supply
Load pressure gain	8500 psi per ma minimum with 3000 psi supply	10,000 psi per ma minimum with 3000 psi supply
Temperature	—65°F to +275°F	—65°F to +275°F
Maximum Null Shift	(% of rated current)	
Temperature Change per 100°F	1%	1%
Supply Pressure Variation ±	2%	2%
Quiescent Current Change 20%	1%	1%
Weight	12 ounces	16 ounces

TORQUE MOTOR: Note: 6103 & 6106 Identical with exception of torque motor characteristics.

	Valve #6103	Valve #6106
Input Power	300 Milliwatts	64 Milliwatts
Rated Current	± 10 ma	± 8 ma
DC Coil Resistance (other motors also available)	3000 ohms/coil	1000 ohms/coil

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

tudinal vibration better than transverse.

✔ Take care during soldering—excessive heat at potentiometer terminals may open internal solder connections.

RELAYS

✔ Use a "back-wave" rectifier to keep DC relays from chatter or buzz when used on half-wave rectifier power.

✔ The "back-wave" rectifier has these advantages over the copper ring and the capacitor:

- The relay's time constant is not altered as much as with the copper ring.
- Weight is generally less.
- Current drawn through the main rectifier during the conducting half-cycle is considerably less than when a capacitor is used across the relay, since it's not necessary to supply energy to charge the capacitor as well as to operate the relay.
- The main rectifier may have a current capacity about 60 per cent of the coil current, and the "back-wave" rectifier about 40 per cent.

✔ Use a diode to protect relay contacts used with inductive loads.

✔ In dry circuits, parallel connection or connecting pairs of contacts in parallel increases the probability of making the circuit on each operation. However, the current rating will not be increased, since the contacts will not make and break simultaneously.

✔ Mount relays so that the direction of motion of contacts is not coincident with the expected direction of shock. Under vibration, relays function erratically and finally fail. The newer relays tolerate from 10 to 15 g in the range of 10 to 2000 cps. Most relays fail at from 2-12 g. Clapper relays are most delicate and rotary are next; plunger relays are the most rugged.

✔ Relays take vibration better when energized than when de-energized.

✔ Relays that have failed under vibration test are more likely to fail again.

✔ The sensitive polar-type relay is more susceptible to acoustic vibration.

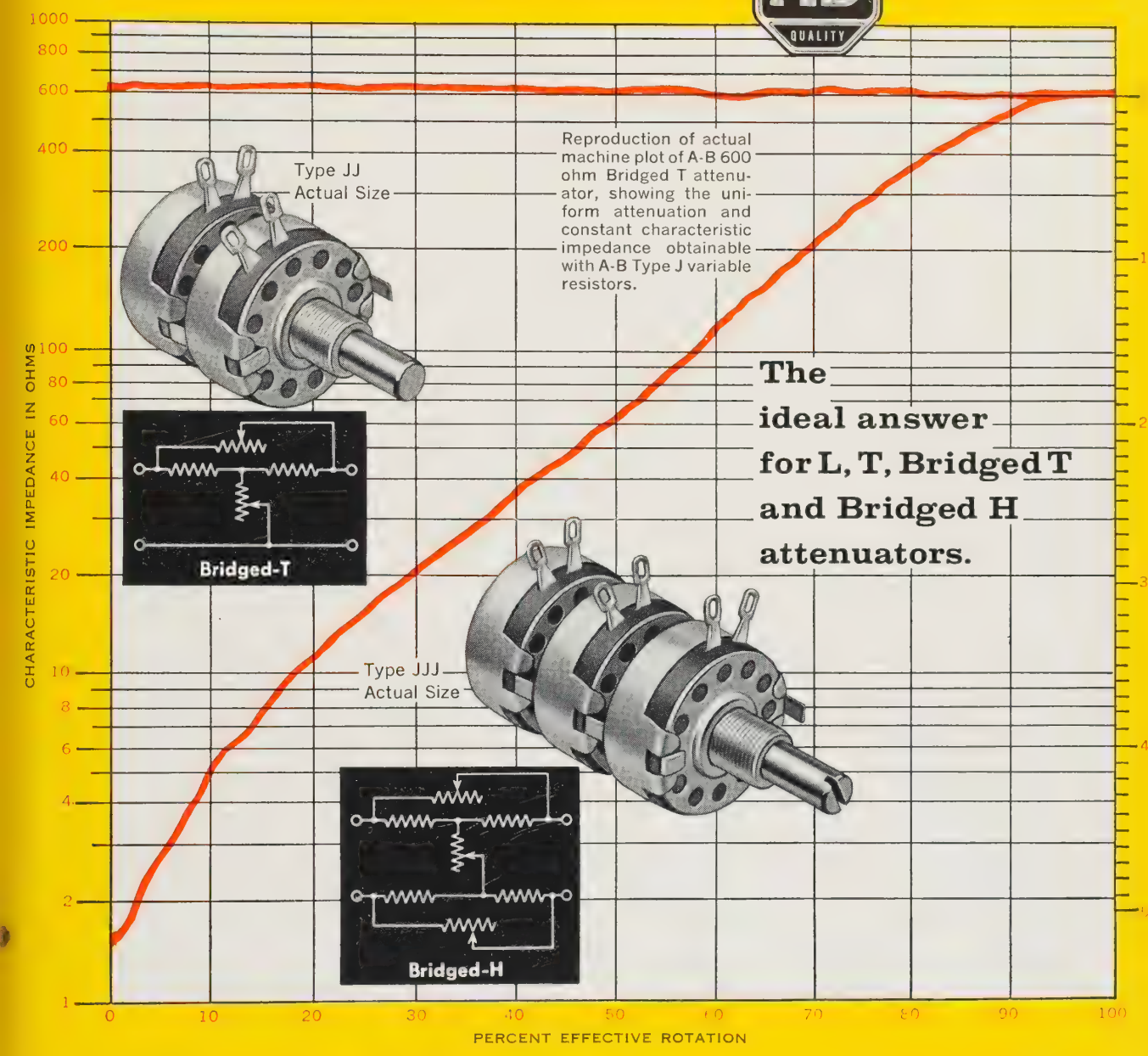
RESISTORS

✔ Resistors suffer temporary

No. 213 on Reader Service Card

No. 168 on Reader Service Ca

Use Low Cost Allen-Bradley Type J Pots for Constant Impedance Attenuators



Allen-Bradley dual and triple Type J variable resistors are widely used in attenuators in electronic circuitry because they provide dependably smooth and uniform attenuation plus constant characteristic impedance.

Stability, high wattage, long life, ideal uniformity, plus remarkable compact structure are combined in the Type J to assure top performance. The solid resistance element—made by A-B's exclusive hot molding process—provides smooth control at all times.

With this precise control over the resistance-rotation characteristics during production, A-B attenuators have a consistently uniform attenuation that approaches calibration accuracy . . . and the characteristic impedance can be held to ±10% over *entire* rotation—*end* to *end*. The virtually infinite resolution eliminates the definite incremental steps of wire-wound units, while freedom from inductance insures excellent high frequency response. For full details on Type J variable resistors, send for Publication 6024.

Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis. • In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

8-61-E

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

Non-Linear Systems, Inc. designs first digital voltmeter to satisfy critical standards for missile work

Digital voltmeters — originated by NLS — permit rapid and accurate voltage measurements. New Series 20 unit — with one plug-in decade board removed — shows the use of Allen-Bradley fixed resistors.

Resistor Failures UNHEARD OF

...naturally, NLS uses ALLEN-BRADLEY hot molded resistors

To satisfy the high standards of consistent accuracy and reliability demanded for missile and weapons checkout, Non-Linear Systems, Inc., developed this digital voltmeter. It uses scores of Allen-Bradley fixed resistors. (For example, the latest Series 20 unit, shown above, contains about 1,000 in each instrument.) "In the selection of A-B resistors," says NLS, "quality and availability have never been a problem."

A-B resistors have such consistently uniform electrical characteristics that their performance can be accurately predicted over long periods of time under various operating conditions . . . with *complete freedom* from catastrophic failure while in service! The hot molding process used exclusively by A-B is the reason for this uniformity and reliability.

To obtain this same measure of superior performance for your equipment, always insist on Allen-Bradley quality fixed resistors available in various types. For full details, send today for your copy of Technical Bulletin 5000 or Publication 6024. Write to: Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis. In Canada: Allen-Bradley Canada Ltd., Galt, Ontario.

ALLEN-BRADLEY Hot Molded Resistors
ACTUAL SIZE

Hot molded composition resistors are available in all standard EIA and MIL-R-11 resistance values and tolerances.

**Pending MIL Spec Assignment*

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENT

changes in value during use—due to temperature, voltage, and moisture—and permanent changes over a period of time. The magnitude and direction of these changes are similar for similar types of resistors. Thus when two or more resistors must maintain a nearly constant *ratio* of values in a circuit, as in voltage dividers and mixers, the same type of resistor (i.e., composition, film, wirewound, etc.) should be used for both.

- Avoid using tapped resistors—insertion of taps weakens the resistor mechanically and lowers the effective power rating.
- Be sure that the power dissipated by composition and deposited-film resistors is not more than 75 per cent of their net rating.
- Use carbon composition and film-fixed resistors with normal ratings for ambient temperatures of at least 70 deg C.
- Carbon-composition resistors are inherently unstable and may vary as much as 15 to 20 per cent beyond their initial tolerance. Don't use where their instability may cause circuit malfunction.
- For carbon-composition and deposited-film resistors, lower the normal voltage rating by at least a third. This insures that the steady-state peak or transient voltages will not be more than 75 per cent of the net voltage rating.
- When resistors are mounted in rows, banks, or adjacent to other parts, space them so that (taking into consideration restricted ventilation and heat dissipation by the nearby resistors and other parts) no resistor will exceed the maximum permissible temperatures.
- In designing equipment, take into consideration resistor wire size —the failure rate increases as the size of the wire decreases.
- Resistance-change due to humidity varies with the resistance value and is less in the lower values. It can be corrected to the original value by conditioning the resistor at 100 deg C for 48 hr.
- Resistors operating at one-tenth rated wattage load are least affected by humidity.
- Resistance-change due to "load life" can be lowered to about one to two per cent by derating the resistor approximately 50 per cent.

solid
state
airborne
TELEMETRY
system

Applied Electronics Corporation of N. J. are producers of the most reliable solid state telemetry systems available today.

Supplied for use on Titan, Minute Man, Sub Roc and other major missile programs with an outstanding record of operational performance. In addition to the company's standard line of PAM, PDM and PCM systems, a new family of satelite telemeters is being produced and supplied for

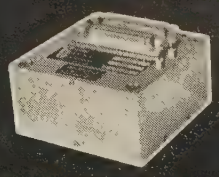
QUALIFIED.....

use on several satelite projects. These equipments are characterized by low power dissipation, small size and high accuracy. Technical Specialization has enabled us to produce the most advanced and reliable completely solid state telemetry systems. Several of these are briefly described opposite.

Applied Electronics Corporation
OF NEW JERSEY

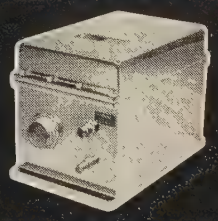
METUCHEN, N. J.
TWX—METU 708
Liberty 9-9200

45 x 20 PDM MULTICODER
MODEL MDH—4 SERIES



PDM Multicoders solid state designed with utmost compactness, highest accuracy with low power dissipation. This equipment contains power supply, commutator and pulse duration modulator. The equipment is also available for low level applications.

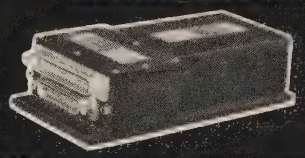
HIGH SPEED SOLID STATE
PCM MULTICODER MCH SERIES



PCM System or digital Telemeter includes a high resolution electronic commutator which accurately samples up to 120 channels, coder and power supply in a package size of 6" x 6" x 9"—the smallest working digital telemeter available today.

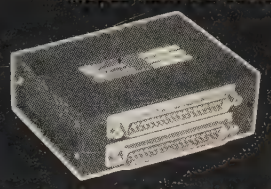
PDM, PCM, PAM

30 CHANNEL LOW LEVEL PAM
MULTICODER MAL-3 SERIES



PAM are available in all standard IRIG sampling and channel configurations, Solid State, high reliability, long life and low power dissipation —also available for low level applications.

30 CHANNEL TWO POLE
SOLID STATE PAM MULTICODER
MODEL MAH-3-2 SERIES



Engineering Specifications are available on all available AEC Designed Equipment, our Engineering and Research, and Design Departments are always available to discuss your specific telemetry problems.

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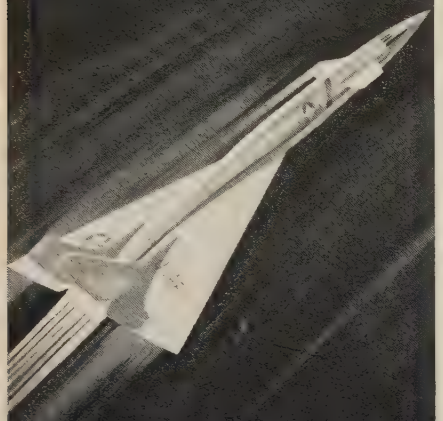
NEW DIMENSIONS IN RELIABILITY



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CUSTOM-DESIGNED SWITCH PACKAGES AND SYSTEMS FOR AERO/SPACE

MASON
Research and development proves the concept of reliability in switches and systems for missiles, aircraft and ground support equipment.

For Reliable Switches and Systems, Contact

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ELECTRIC CORPORATION
Specialists in Switching Systems
3839 VERDUGO ROAD, LOS ANGELES 65, CALIF.

No. 215 on Reader Service Card

Table II gives representative relative costs of fixed resistors of comparable electric size.

COMPOSITION RESISTORS

Properly used, common composition resistors (Mil-R-11) are very long-lived. They are available in a wide range of values and in ratings of from 0.1 to two watts. In use they are rather unstable—they may drift with time as much as 15 per cent from their original value, due to the permanent effects of humidity, temperature, and applied voltage. Reversible changes due to temperature and voltages cause temporary value changes in operation. They continue to act as resistances, however, up to several megacycles of working frequency.

If your circuit cannot take a 15 per cent permanent change of resistance over several thousand hours, choose another kind of resistor, or preferably, make your circuit more tolerant of component changes.

If small drift is essential, keep composition resistors away from moisture, either by encapsulating the equipment, by keeping the equipment warm at all times, or by other means.

Variable-composition resistors (Mil-R-94) are sensitive to heat, moisture, and voltage. They should not be used where long-term stability is required. In most uses only part of the resistance element is used and the power rating must be reduced proportionately.

FILM-TYPE RESISTORS

Film-type, low-power resistors are much more stable than composition resistors and have excellent high-frequency characteristics. The varnish-coated varieties are uninsulated, for all practical purposes, and are fragile and sensitive to heat. They must therefore be handled carefully. Extreme heat from soldering can permanently change their resistance value. Keep uninsulated units away from organic solvents which may wash away varnish coatings and markings.

Film-type resistors are available in several forms, the deposited carbon, oxide coated, and metal film varieties being the most common. Normal tolerance of new units is ±1 per cent but individual resistors

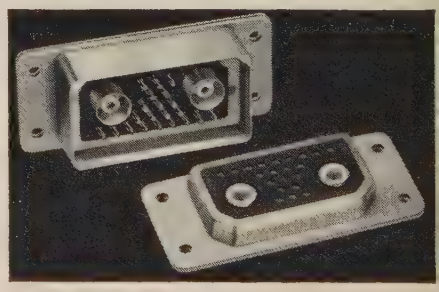
DESIGNED TO MEET THE CHALLENGE OF ENVIRONMENT

Connectors

Strength . . . Endurance . . . Survivability . . . The Albatross is well equipped to live at sea and in the air almost continually. Airborne missiles, too, are designed for capable operation under rigorous environmental conditions. That is why Anton Series S-20 Miniature Connectors by Lionel are specified whenever utmost reliability is essential for plug-in type sub-assemblies.

- *Positive alignment & polarization*
- *Minimum mated depth*
- *Extended insertion/withdrawal life*
- *4 sizes: 13 to 41 high voltage contacts, 2 & 4 coaxial contacts & combinations*
- *Meet applicable MIL Specs*

(Special materials and modifications to meet specific requirements)



Delivery time slashed for Anton "special" connectors! New Lionel tooling practices provide rapid delivery of "specials" for unusual applications... within 6-8 weeks* of order date!

*"Standard" catalog units are in-stock items.

Write Dept. 412-W for Series S-20 Technical Literature.

LIONEL
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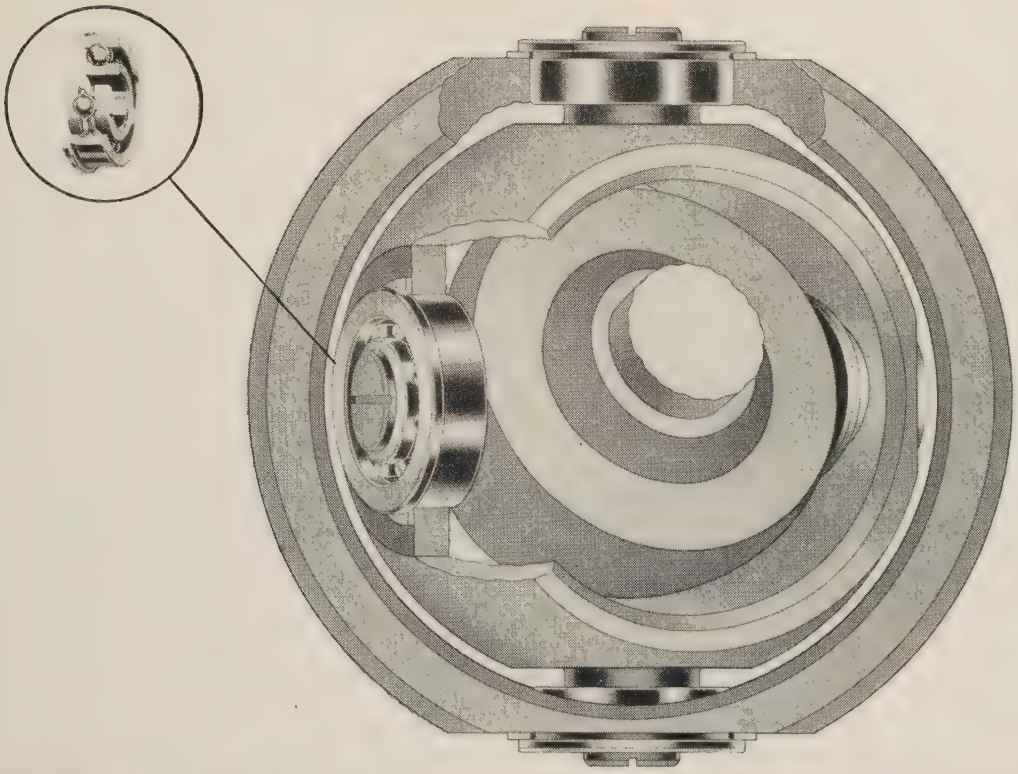
FORMERLY ANTON ELECTRONIC LABORATORIES
1226 Flushing Ave., Brooklyn 37, N.Y.

No. 216 on Reader Service Card

BARDEN "W" retainer bearings
reduce torque peaks...
eliminate retainer lock...
deliver uniformly low-torque performance



Low-torque bearing reliability for gyros, synchros, other torque-sensitive instruments

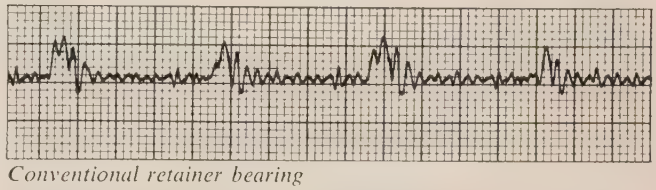
Torque peaks that fail to show up on most torque tests can result in erratic performance of gyro gimbals, synchros, potentiometers and other instruments demanding uniformly low torque or exceptionally smooth operation. To solve this reliability problem, Barden developed the "W" retainer bearing.

The "W" retainer is a thin-section, free-fitting stainless steel ball cage with formed pockets. Its design reduces internal bearing friction, cuts down torque peaks and eliminates retainer lock (wedging of balls and retainer under radial or combined axial-and-radial loading, or as a result of misalignment).

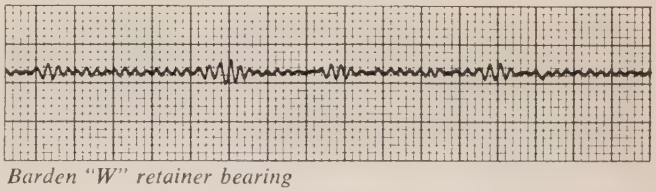
Barden "W" retainer bearings have higher load and speed capacity than spring retainer bearings, yet have the same advantage of low-torque operation under misalignment. Compared with conventional ribbon retainer bearings, "W" retainer bearings have lower overall torque and greatly reduced torque peaks, particularly under radial or combined loads (see traces at right).

Data Sheet Available

New data sheet lists 81 *Barden Precision* "W" retainer bearings now available in 16 standard miniature and instrument sizes, flanged and unflanged, shielded and open, from .0469″ to .2500″ bore and .1562″ to .6250″ O.D. Ask for Data Sheet W-3.



Conventional retainer bearing



Barden "W" retainer bearing

In torque test (4.5 lb. radial load, 18 rpm, no induced vibration) conventional ribbon retainer instrument bearing develops peaks 11 gm-cm above average torque. Barden "W" retainer bearing shows torque peaks of only 3 gm-cm under same test conditions. Traces show high torques possible in actual operation under radial loading. These cannot be compared with readings from MIL-STD 206 testers which show torque under thrust load only.

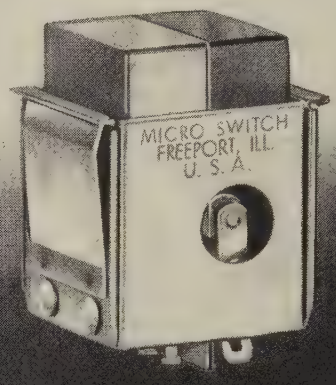
Traces: actual size. Scale: 1 mm = 2 gm-cm.

BARDEN
PRECISION BALL BEARINGS

THE BARDEN CORPORATION, 220 Park Ave., Danbury, Conn., Pioneer 3-9201
3850 Wilshire Blvd., Los Angeles 5, Calif., DUnkirk 5-0034

HONEYWELL

MICRO SWITCH Precision Switche



NEW! ALTERNATE ACTION LIGHTED PUSHBUTTON

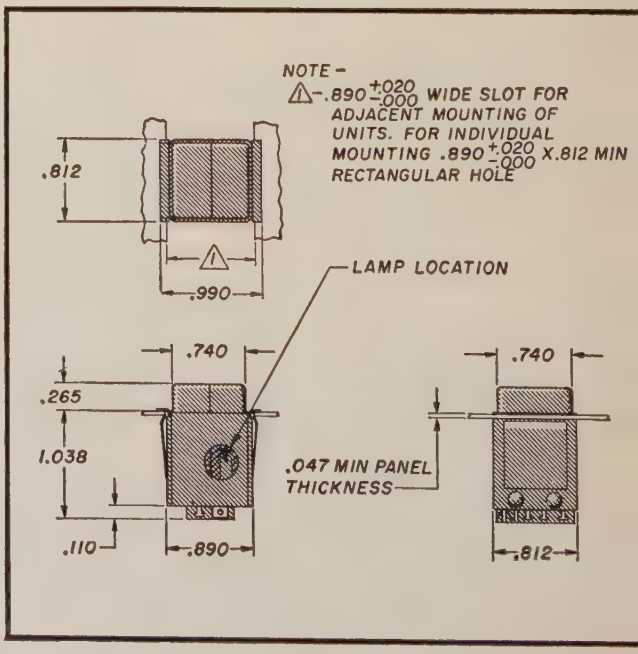
Reliable snap-action switches

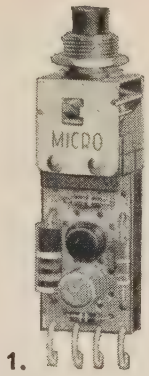
Here is a new concept in ultra-small pushbutton switches for control with integral simultaneous visual indication. Switches in this series are designed for control panels in missile, rocket, launcher, marine and ordnance applications—wherever space and weight are important factors.

In less than one cubic inch: double-pole double-throw switching; two integral lamps; choice of 15 combinations of two-color display screens. Alternate-action operation (push on—push off). Designed to conform to MIL-S-6743, MIL-S-6744, and MIL-E-5272.

Within the assembly are two SPDT switches, rated 7 amps. 115-230 vac or 28 vdc. A 5-volt sub-miniature lamp is under each half of display screen and there are 15 combinations of color display available. The complete unit snaps into panels 0.047 in. thick or greater. No installation tools needed. Minimum mechanical life is 100,000 operations. Lamp life is 60,000 hours at rated load.

Available in the same size are a momentary-action switch, and an indicator unit without switching function.





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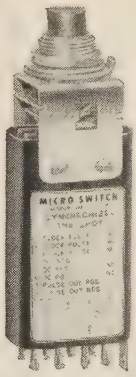

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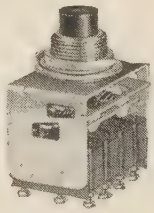

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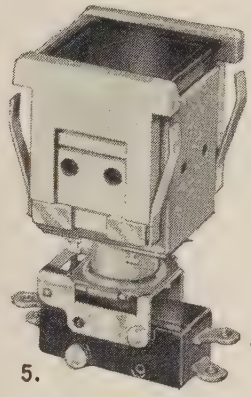

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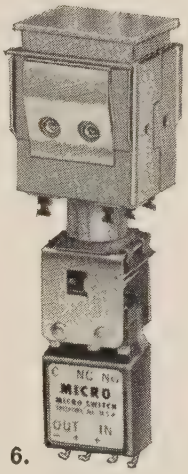

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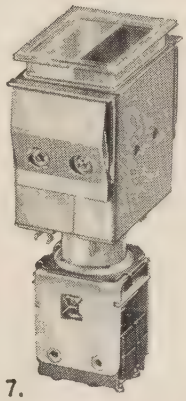

7.

8.

for control panels

CUSTOM-BUILT CONTROL PANELS REQUIRE CAREFUL SELECTION OF SWITCHES

Immediately available are hundreds of small size switch units with variations in dimension, electrical capacity, shape, appearance and circuitry. All have undergone thorough tests in the most complete test laboratory of its kind.

Shown above and briefly described here are only a few of the hundreds of types of switch assemblies available.

1. Electronic switch-circuit for bounce-free voltage output.
2. Light force, rapid repeat pushbutton.
3. Synchronized "one-shot" pulse circuit.
4. Compact, 4-pole snap-action pushbutton.
5. Lighted pushbutton, modular design, barrier mount.
6. Lighted pushbutton, electronic "one-shot" switch-circuit.
7. Two-color lighted pushbutton, snap-in flange mounting.
8. Bushing mount lighted pushbutton, high capacity, 2-ckt switch.

For more information and for experienced help in selection, contact one of our many branch offices listed in the Yellow Pages, or write for Catalog 67 and Bulletin 22.

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A division of Honeywell
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MICRO SWITCH Precision Switches

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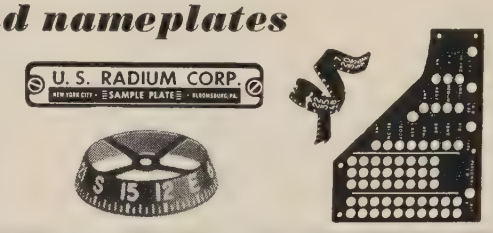

radiation sources

Sealed beta, gamma and neutron sources/Bulletin 20.40 B
Ionization sources for electron tubes/Bulletin 13 B
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Tritium foils and targets/Bulletin 20.70 B

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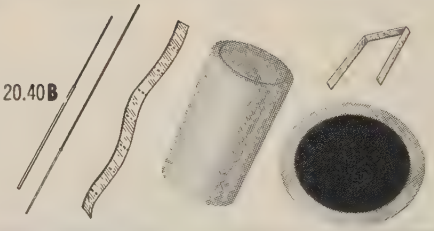

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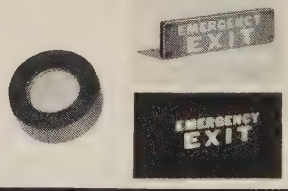

phosphors

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geiger-mueller tubes

In stock—highest quality, economically priced G-M tubes distributed exclusively in USA for Electronic Associates Limited of Canada /Bulletin EAL B

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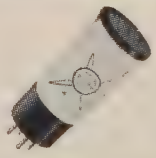

ion generating equipment

Selective ion generators/Bulletin 60.30 B
Dynamic Ionaire® Mark VII negative ion generator/Bulletin 60.23 B

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US RADIUM

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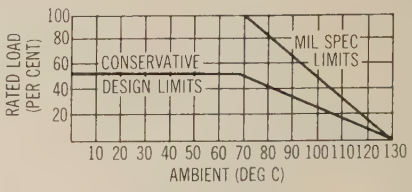
MORRISTOWN, N. J. | Offices: Chicago, Illinois and North Hollywood, Calif. Subsidiaries: Radelin Ltd., Port Credit, Ont., Canada and U.S. Radium Corp. (Europe), Geneva, Switzerland.



TYPICAL temperature-derating curve for freely ventilated resistor. Note: Composition resistors cannot be used above 130 deg C ambient.

may permanently change in value as much as five per cent after several thousand hours of use. For best long-term reliability, derate the resistors by 50 per cent. Where environment demands it and price permits, use encapsulated or hermetically sealed forms. These resistors have much lower temperature and voltage coefficients than composition resistors. (See *Graph* for derating.)

There are also several varieties of high-power, film-type resistors (Mil-R-11804) on the market. These generally can be obtained in resistance values higher than corresponding wirewound resistors and should be used instead of the latter in high dissipation applications.

WIREWOUND RESISTORS

Wirewound resistors are stable and are little affected by moisture or aging. Since resistance increases with temperature, precision resistors must be operated at low-power rating to minimize resistance change due to heat, which accounts for their large size. Even "non-inductive" wirewound resistors are highly inductive, and normally cannot be used at frequencies above 50 kc.

Encapsulated varieties must be used in permanent equipment—the paper-wrapped, bobbin-wound resistors are very fragile and are subject to mechanical damage both at installation and in service.

Precision resistors using less than 1.5-mil wire should not be used.

Precision wirewound potentiometers (Mil-R-12934) are most commonly used in servomechanisms, analog computing circuits, and precision instruments. They can be designed to provide a variety of non-linear and linear functions. Precision potentiometers are expensive

No. 169 on Reader Service Card

AN ACHIEVEMENT IN DEFENSE ELECTRONICS

New Transportable Radar Directs Precision Air Support

Front-line ground forces can now obtain all-weather, close air support, —when and where needed—with the new lightweight AN/TPQ-10. This is the first helicopter-transportable, high-accuracy control radar for precision air support. Developed for the U. S. Marine Corps by General Electric's Heavy Military Electronics Department, the versatile new system can also provide aircraft control for emergency supply airdrops, paratroop placements and aerial mapping. 176-07

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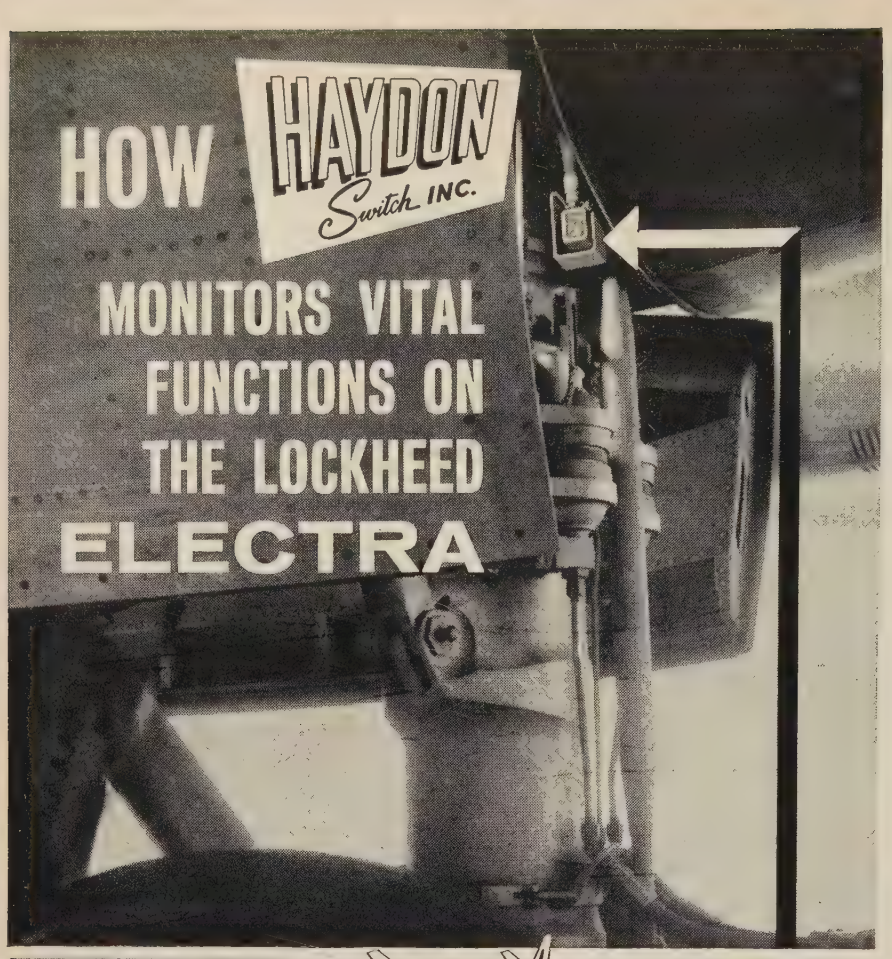
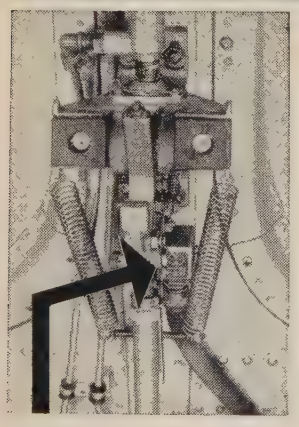
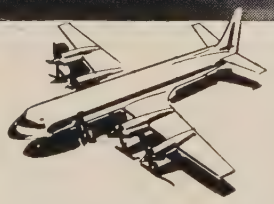
Progress Is Our Most Important Product

GENERAL ELECTRIC





Another No. 40108 Haydon Switch actuates a visual indicator in the cockpit when landing gear is **UP** and **LOCKED.**



This No. 40108 sealed limit switch shuts **OFF** cabin pressure system when landing gear is down, turns **ON** cabin pressure system when landing gear is up.

Both of these limit switches are hermetically sealed, externally mounted and exposed to water, mud, snow, ice and of course constant changes in pressure.

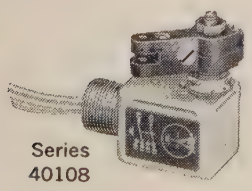
Actuation in this vital application is positive. Haydon Switch has also contributed other unique features that offer increased latitude to sealed limit switch applications.

360° adjustable actuating arm.

Capable of LEFT and RIGHT hand operation. Eliminates stocking problems.

Small angular ON and OFF differential.

Extremely sensitive indication especially where limited motion is available.



Series 40108

Series 61162

Series 9151

Series 61574

HAYDON Switch INC.

Send for Catalog showing Haydon Switch Inc. Limit Switches and a complete line of snap action switches, switch assemblies and pressure switches.

WATERBURY 20, CONNECTICUT PLaza 6-7441

and are specified only when high stability and accuracy are needed.

✔ Wirewound power-type resistors (Mil-R-26) are designed for high temperatures, but will dissipate rated power only when well ventilated. These units may develop hot-spot temperatures as high as 275 deg C, and must be isolated from components that may be damaged by heat.

✔ Adjustable wirewound resistors should not be used on permanent equipment—they may lose their adjustment and the movable taps can abrade the resistance winding. If they must be used, check your reliability group for their effect on the reliability of your specific equipment. Mil-R-18546B covers a chassis-mounted version of this resistor. Power rating is based on chassis or heat sink size.

✔ For best reliability, power resistors using less than 2.5-mil wire should not be used. The limitation on wire size, both for precision and power-type resistors, naturally limits the upper value of resistance that can be obtained. However, these limits must be observed, since the life of resistors in operating equipment is much less for the high-value varieties wound with small wire.

RESOLVERS

✔ Although not nearly so popular for precision application, special resistance potentiometers used as resolvers offer some advantages. Of particular importance are their suitability for DC applications and their freedom from phase-shifts and residual (null) voltages. On the negative side, they suffer from noise at the brush contacts, higher friction, relatively poor resolution in wirewound types, shorter life, and lower maximum operating speeds.

✔ Alternate means of electromechanical sine-wave generation are:

- Cam and follower coupled to pick-off;
- Sinusoidal gearing coupled to pick-off;
- Mechanical linkage mechanism, such as scotch yoke, driving pick-off;
- Internal-gearing arrangements for generating sinusoidal motions.

✔ Used in a Mach computer, a resolver gives better accuracy, reliability, and life than a feedback

No. 226 on Reader Service Card

HARNESSING THE ELECTRON BEAM

WHAT IS E-BEAM EQUIPMENT? WHAT DOES IT DO? CAN IT BE PUT TO WORK FOR YOU ECONOMICALLY?

WHAT IT IS: Alloyd Electronics' electron beam equipment consists of a line of completely self-contained units employing electron bombardment heating, carried out in a vacuum, for evaporating, welding, brazing or zone refining.

MAJOR APPLICATIONS:

Evaporation: Alloyd electron beam equipment can be used to produce high purity thin metallic and non-metallic films by vapor deposition of high temperature materials. Films can be made from the most difficult materials, including beryllium, tantalum, silica, alumina.

Useful thin-film applications: Electronics, where thin films can perform as capacitors, resistors, magnetic memory devices, etc. . . . optics, where thin films with unusual optical properties are being developed . . . and countless other applications.

Welding: Alloyd Electron Beam Welders (see below) are designed for experimental or production welding and brazing of refractory and reactive metals. High vacuum is coupled with high power density — makes possible contamination free, narrow heat affected zone welds in titanium, beryllium, tungsten, molybdenum, etc.

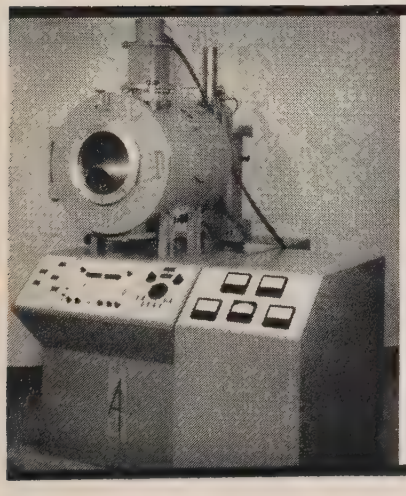
MAJOR ADVANTAGES OF ALLOYD EQUIPMENT:

1. Modular design, for flexibility: basic components of any Alloyd system, including electron gun and power supply, vacuum chamber, and vacuum pumping system are available in practically unlimited combinations for maximum flexibility, and can be easily and economically tailored to any application. 2. Voltage is low and safe (30,000 volts max.) eliminating x-ray hazards to the operator. 3. Maintenance is simplified. For example, the electron gun filament in any Alloyd unit can be serviced without removing the gun. 4. Operation is simplified. Fingertip controls, located directly underneath the chamber, make for maximum operating ease and efficiency.

Benefits to be derived from Alloyd's look-ahead modular design are both numerous and substantial, not only in terms of reliability, but in terms of flexibility and cost.

It will be well worth your while to write today for complete information.

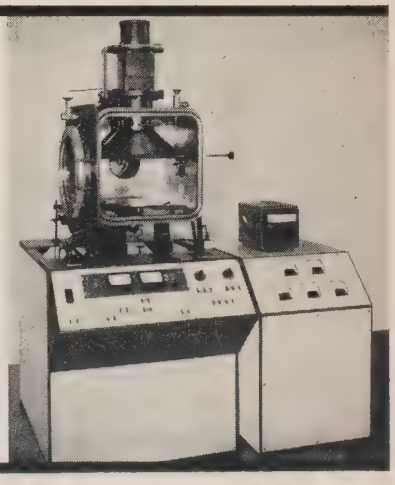
alloyd electronics corporation 35 Cambridge Parkway, Cambridge 42, Massachusetts



Mark VI Electron Beam Welder — for clean, crack-free welds in even the most refractory and reactive metals by electron bombardment. High vacuum eliminates contamination. Ultra-narrow heating zone permits optimum control and precision in handling very thin pieces or welding thin-to-thick sections.

Mark V Electron Beam Evaporator— a reasonably priced, highly flexible unit for producing thin metallic and non-metallic films by vapor deposition through electron bombardment heating. Completely self-contained. An invaluable research and development tool for thin-film applications, including micro-miniaturized electronic circuitry, optical filters, resistors, capacitors, memory devices, countless other components.

The Electron Beam at your service — Our laboratory is part of an advanced, complete facility for electron beam welding, brazing, evaporating, melting and zone refining maintained by Alloyd to meet custom requirements. We also offer engineering, consulting and R&D services in systems design and development. Ask us for complete information.



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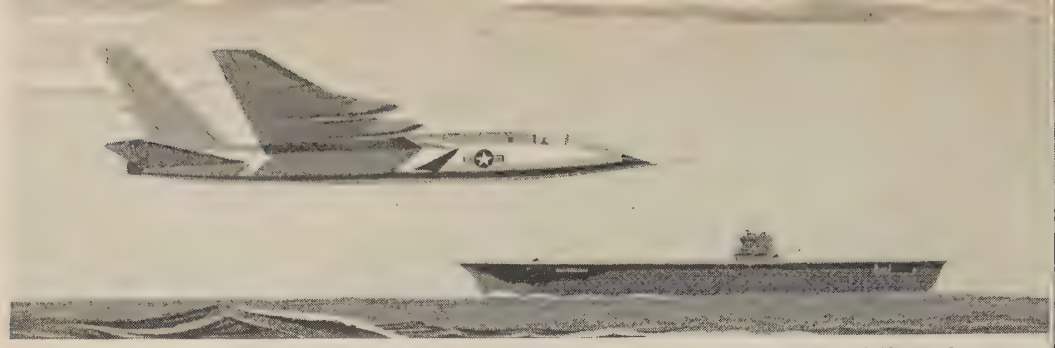
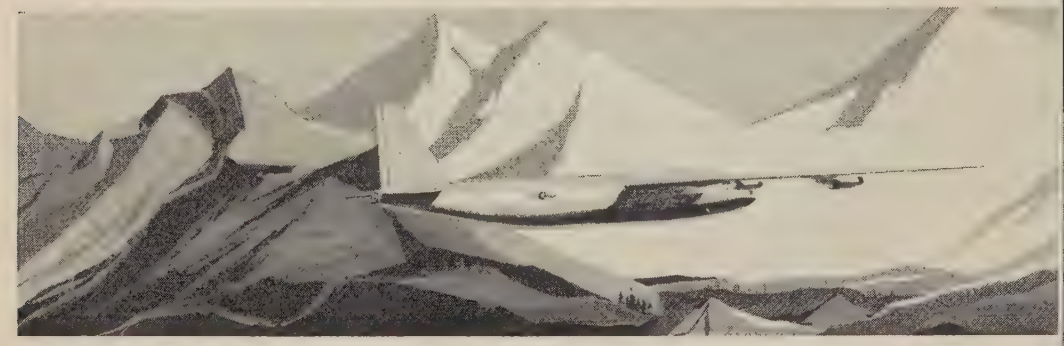
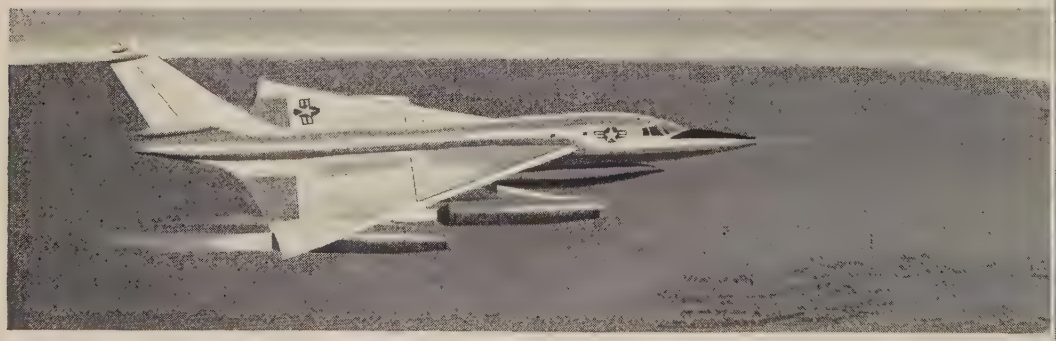


NAVIGATION — Raytheon in 1958 developed a highly sophisticated Doppler Navigation System for the U.S. Navy's A3J. This system was the forerunner of an advanced Raytheon Doppler System now operational in the U.S. Air Force's B-58.



TERRAIN AVOIDANCE — Raytheon designed and is producing the U.S. Air Force's only operational low-altitude target acquisition radar. It is currently installed on the Strategic Air Command's B-52 intercontinental bomber.



BOMB-NAVIGATION SYSTEMS — Raytheon developed and produced an integrated radar-radome for the high performance B-58. With the Raytheon Doppler System (the most accurate in use today, despite severe environmental conditions) these radars are vital elements of the Hustler's bomb-navigation system.

Raytheon brings proven capability t

Experience and achievements give ample proof of Raytheon's ability to develop and produce operational equipments that would enable high-performance aircraft to carry out the deep penetration-low altitude attack mission: ■ Raytheon Doppler navigation radars for the A3J and B-58 ■ Raytheon terrain avoidance radars for the B-52 ■ Raytheon bomb-navigation radars for the B-58 ■ Raytheon low altitude guidance systems for interceptor missiles.

Add to these Raytheon's selection as prime contractor-systems manager for the U.S. Army's and Marine Corps' HAWK and the

the low altitude attack mission

U. S. Navy's SPARROW III missile systems; as producer of the 2nd generation Polaris' advanced guidance system; and as systems manager of the ARPAT Terminal Defense System program.

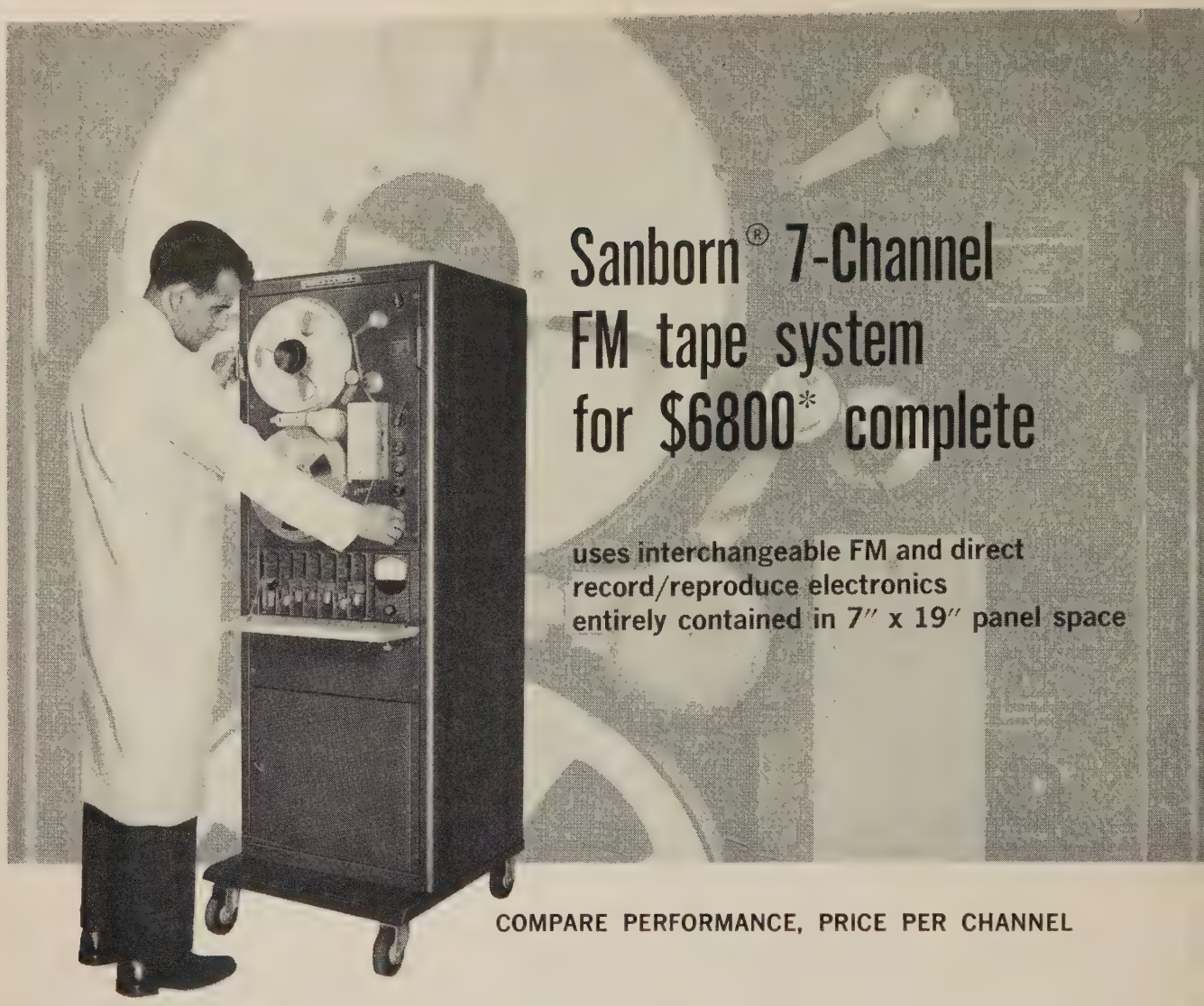
One of the world's largest scientific-industrial organizations, Raytheon can create the required technology and manage every phase of a complex defense or space system — from early study and design through development, production and field support of operational systems and equipment.

Missile and Space Division, Bedford, Massachusetts.

RAYTHEON COMPANY

MISSILE AND SPACE DIVISION

RAYTHEON



Sanborn® 7-Channel FM tape system for $6800* complete

uses interchangeable FM and direct record/reproduce electronics entirely contained in 7″ x 19″ panel space

COMPARE PERFORMANCE, PRICE PER CHANNEL

Here is the ideal combination of high performance *and economy* in a 7-channel, 4-speed system that meets IRIG Telemetry Standards. *Versatility* is another advantage. The Model 2000 system uses interchangeable Sanborn FM or direct record/reproduce electronics — all solid-state, in 7″ of panel space — and you can have any combination of direct and FM channels simply by changing circuit cards. Recording capability may be extended beyond the system's minimum input levels through the use of Sanborn "850" and other compatible amplifiers.

The Model 2000 Magnetic Data Recorder has four speeds and uses standard ½-inch tape on 10½-inch reels. All controls are on the front, and several convenience features are included: an integral FM Alignment Meter that eliminates the need for electronic counters, an automatic squelch, a tape footage counter, and provision for using one channel for flutter compensation.

Complete details are available from Sanborn Sales-Engineering Representatives in principal cities throughout the U. S., Canada and foreign countries.

**Price FOB Waltham, Mass., in Continental U. S. A.; subject to change without notice. State and local taxes must be added where applicable.*

(Specifications subject to change without notice)

SPECIFICATIONS

Input ± 2.5 V into 10,000 ohms, single ended, adjustable.

Output ± 2.5 V into 1,000 ohms or more, single ended; level, position adjustable.

Bandwidths (Max)

Speed	*FM*	*Direct*
3¾″/sec	0-625 cps	50-6,250 cps
7½″/sec	0-1,250 cps	50-12,500 cps
15″/sec	0-2,500 cps	50-25,000 cps
30″/sec	0-5,000 cps	100-50,000 cps

(100% modulation on FM = ± 40% carrier deviation)

Linearity Maximum error due to nonlinearity: 0.2%.

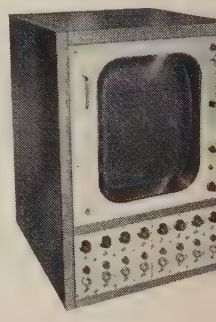
Drift ± 0.5% of full scale for 10 V power line change, 10°C ambient temperature change, or for 24 hours at constant power line voltage and ambient temperature.

Signal-to-Noise Ratio (Min)

Direct: 40 db at all speeds.

FM: 40 db RMS at 30″/sec and 15″/sec; 35 db RMS at 7½″/sec; 33 db RMS at 3¾″/sec.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts



Readout, as well
input monitorir
during magnetic
cording, may be pr
vided by th
compatible 17-inc
8-channel Viso-Sco
or other Sanbo
monitoring instr
ments, or by dir
writing systems.

No. 230 on Reader Service Card

potentiometer. For proper scaling, a precision transformer is usually required to excite the potentiometer. This is not necessary with a resolver, since the transformation ratio can be adjusted to provide correct scaling.

✓ For precise operation, resolver dimensions and fits over the entire specified range of ambient temperature must be carefully controlled. Temperature coefficients of the major structural members must be matched to avoid differential expansions that may cause sloppy fits or strains of interference. For example, the mismatched coefficients of expansion between a housing and a stator lamination stack may cause interference at some temperature extremes that distorts the stack and shifts the electrical axis.

✓ Balance primary and secondary impedances for best accuracy.

✓ When only one input and/or output winding is used, be sure that the unused winding is properly terminated.

✓ Space harmonics cause angular inaccuracy. They are harmonics in the distribution of flux in the air gap of the resolver and may be determined as a percentage of the fundamental by a Fourier analysis of the flux-distribution pattern.

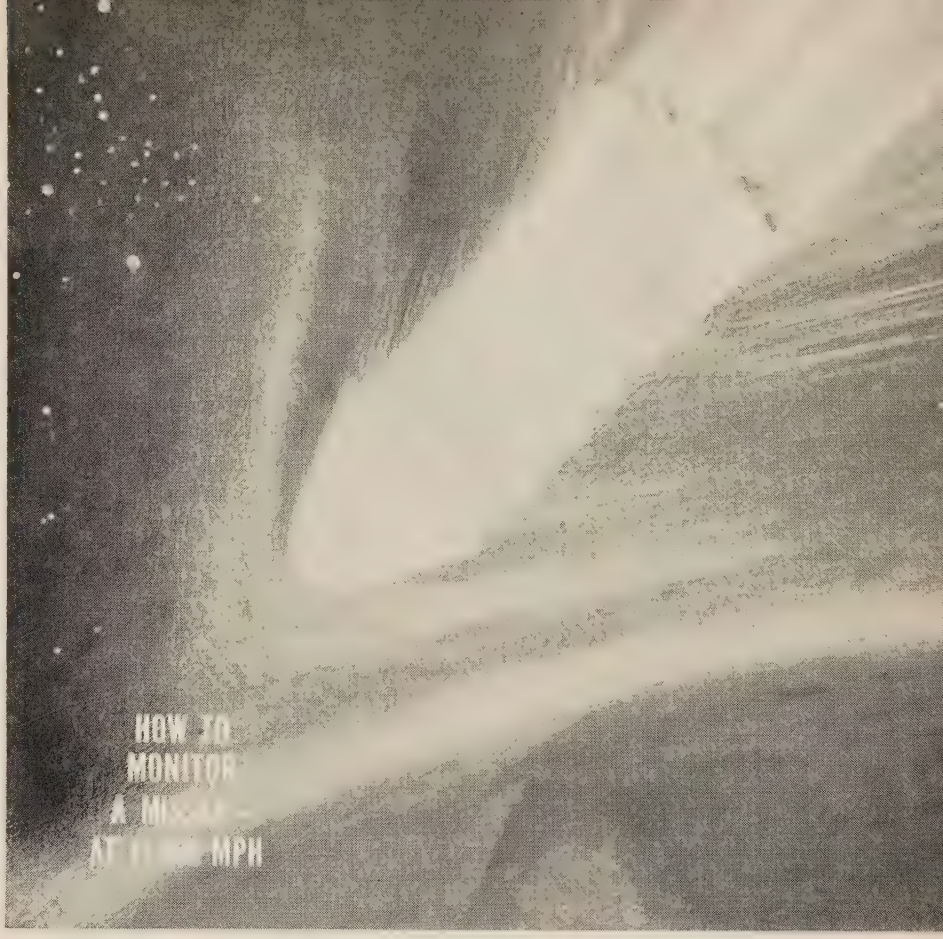
SERVOS

✓ Keep in mind that, when the motor drives a negligible load, the maximum acceleration the load can accurately track is the theoretical stall acceleration divided by the gear ratio.

✓ To obtain maximum acceleration of an inertial load (J_L,) use the optimum gear ratio $[(J_L/J_m)^{1/2}$, where J_m is the motor inertia]. The maximum load acceleration for this ratio is $T_S/(J_L J_m)^{1/2}$. In this instance, the ratio of stall-torque to the square root of motor inertia is a figure of merit.

✓ Where a motor is needed to track servomechanism input signals out to high frequencies, a minimum time constant is a measure of quality. The relation of reversing time to time constant is a simple proportion.

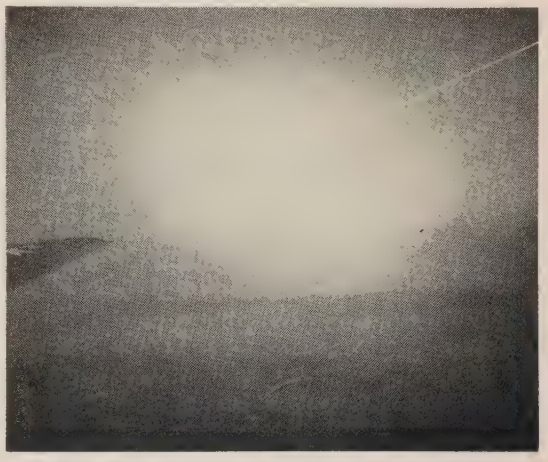
✓ Since servo life depends very sharply on motor temperature, attention must be paid to mounting (a heavy heat sink is best), cooling,

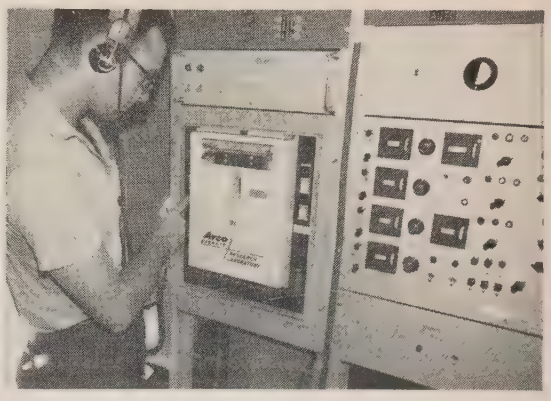


Spectacular as it is, a Titan take-off from Canaveral is only one end of the story. Moments after the shoot, nine thousand miles downrange, an airborne monitoring team is alerted to record the other end of the story as the re-entry vehicle plunges into the atmosphere at 15,000 mph.

Aboard the re-entry monitoring aircraft, a battery of photographic, photoelectric, and radiometric devices captures the dramatic end of the flight. A P.I. instrumentation tape recorder, operated by an Avco-Everett Research Laboratory monitoring team, is used to preserve on magnetic tape a precise record of important radiometric and time-sequence information...data which is essential in the development of advanced re-entry vehicles and in the country's anti-missile program.

One reason a P.I. recorder was selected for this program is that it provides full-size instrumentation performance in a fraction of the space. You'll be interested, if you record any type of scientific data, in other characteristics of P.I. recorders. For details, write for our current brochure.





Above — Photo of Titan missile re-entry. Below — Recorder installation aboard the monitoring aircraft. Photos courtesy of Avco-Everett Research Laboratory.

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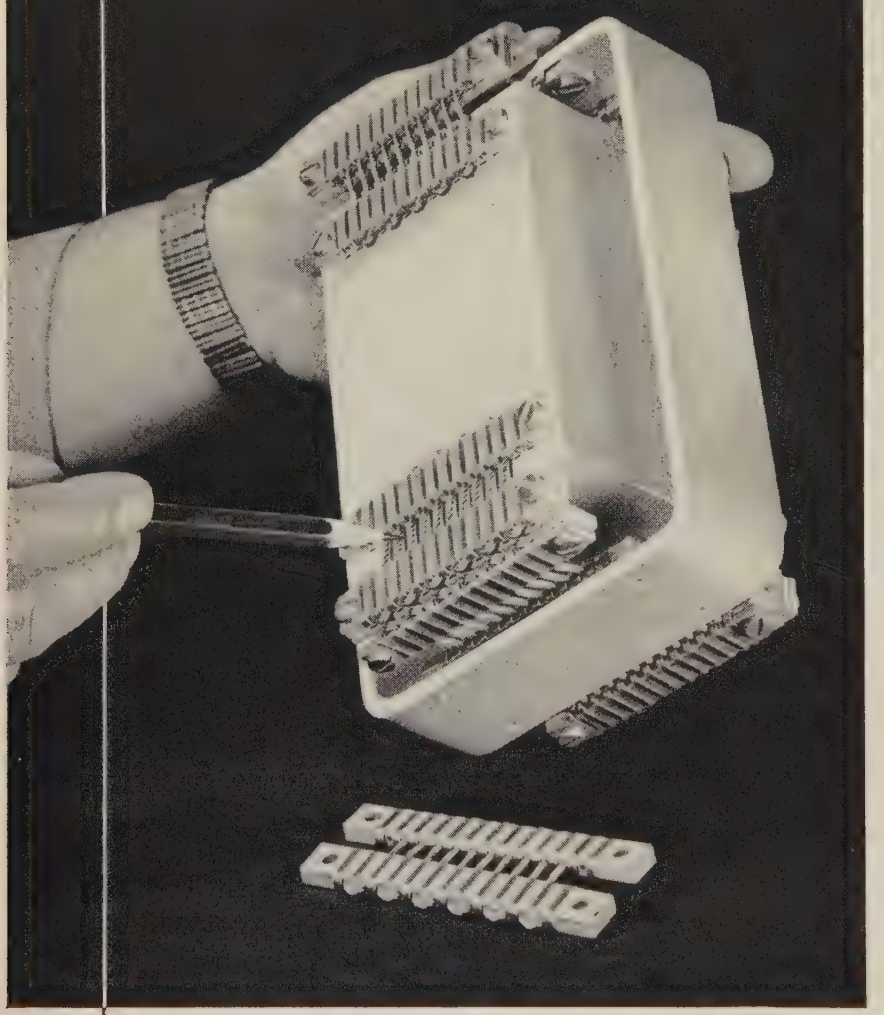
DETUNE VIBRATION ISOLATE SHOCK

From Aeroflex Laboratories—a major development in the control of vibration and shock—the all new field-proven Cable Isolation System.



NOW YOU CAN:

- Isolate your equipment against shock, vibration and noise, or any combination thereof—even in the presence of constant or long term "G" loading.
- Have three dimensional, all attitude isolation.
- Tune your isolation system in the field.
- Have a vibration control system that does not bottom out under heavy "G" loading and functions in a wide variety of environmental conditions including a temperature range of −100°F to +1000°F.

For information on how an Aeroflex Cable Isolation System can be used to solve your vibration and shock problems, write today to Dept. FB-4.

THE AEROFLEX CORPORATION

AEROFLEX LABORATORIES

DIVISION

34-06 SKILLMAN AVENUE • LONG ISLAND CITY 1, N. Y.

duty cycle, and required output. Current best commercial practice is, very roughly, several hundred hours of life in a mounted motor at rated output in 180 deg C ambient temperature.

Keep in mind that output capacity of a servo motor is limited, not by the ability of the motor to deliver torque, but by the ability of the gearhead to transmit the high output torques reliably.

SUPPRESSORS

The simplest suppression component is a *capacitor* that provides a low-impedance path to ground for unwanted currents. It is a shunt-connected device; its impedance must be low at the frequency to be suppressed. Button, postage-stamp, and the several forms of ceramic feed-through types are widely used.

Make sure suppressor capacitors are connected with the shortest possible leads. The combination of capacitance and lead inductance becomes resonant at some frequency, and at this point the capacitor acts as an anti-resonant, high-impedance circuit.

Feedthrough capacitors, properly applied, most nearly approach the ideal capacitor (no inductive component) for suppresion effectiveness.

Use bypass capacitors where the feedthrough capacitors are not feasible or unnecessary.

Use ceramic bypass capacitors for interference suppression in the UHF range.

Check the following rules of thumb:

- A suppression capacitor's X_c must be at least 10 times the combined resistance and reactance of the actual load.
- The maximum recommended capacitance for 125-V, 60-cycle systems is 0.17 uf, and for 250-V 60-cycle systems, 0.085 uf.
- Suppression capacitors must be applied at all power lines.
- The maximum current safely drawn by a suppression capacitor without endangering personnel is nine ma.
- Use suppression capacitors across switches, either alone or with a resistor, to reduce the generation of radiated interference.
- If a suppression-capacitor is

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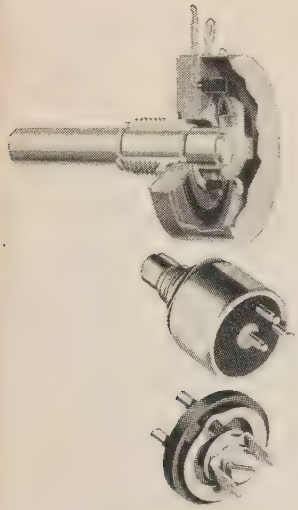
Centralab® :a RELIABLE source for

RELIABLE PRODUCTS

FOR MILITARY & COMMERCIAL APPLICATIONS

Most CENTRALAB products are available for immediate delivery in industrial quantities at factory prices, from CENTRALAB stocking distributors.



HOT MOLDED COMPOSITION VARIABLE RESISTORS

Meet MIL-R-94 environmental and test requirements. Provide smooth noise-free operation and high stability for which hot molded units are well known.

2 WATT @ 500V—Raised resistance track reduces surface contamination. Wide clearance between bushing and collector track for increased high voltage stability. Carbon collector and pick-off brushes.

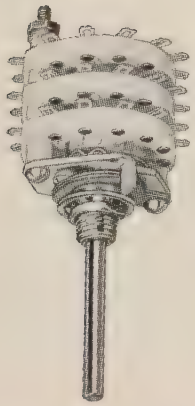
1-3/32″ diam., 5/8″ deep. 500 ohms—5 meg, linear taper; 10K-2.5 meg log taper.

3/4 WATT @ 350V—Metal enclosed units, available with triple "O" ring shaft seal. 23/32″ diam., 1/2″ deep. Same resistances as 2 watt unit.

1/2 WATT @ 350V—Similar construction as 3/4 watt. 1/2″ diam., 15/32″ deep. 100 ohms—5 meg, lin. taper.

1/3 WATT at 350V TRIMMER—locking type variable fixed resistor. Extremely resistant to shock vibration, acceleration, can be encapsulated. 19/32″ diam., 11/32″ deep. 50 ohms—5 meg, linear taper.

Write for Group G bulletins.



ELECTRONIC SWITCHES

Subminiature rotary—15/16″ diam. for military and high reliability applications. Rating 0.5 amp. at 6VDC, 100 ma. at 110VAC. Laminated phenolic, steatite, single or multiple sections.

Miniature rotary—1-1/4″ diam. for military and high reliability applications. Rated 2.0 amps. at 15VDC and 250 ma. at 110VAC. Available single or multiple ceramic, Mycalex and phenolic sections.

Standard rotary—1-5/16″ diam. laminated phenolic or steatite insulation, single or multiple sections. Rating 2 amps. at 15-VDC. 150 ma. at 110VAC. (Resistive load.)

Heavy-duty power—For transmitter, industrial control, laboratory testing, military, commercial. 2-13/16″ diam. 7-1/2 amp. rating at 110VAC. 25,000 cycles minimum.

Spring return—1-5/16″ diam., coil or C-type springs, phenolic, steatite, single or multiple sections.

Specialized—Lever, slide, tone, tuner sections, others.

Write for Group P bulletins.

PACKAGED CIRCUITS

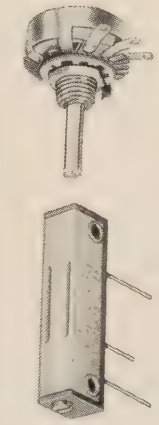
Complete computer and Radio-TV circuits, amplifiers, oscillators, detector networks, resistor networks—including transistors, capacitors, resistors, wiring and inductance, manufactured to your specific performance limits.

PEC* circuits result in substantial savings in assembly costs. These high reliability packaged circuits can be supplied in a wide variety of terminals for printed circuit board applications.

1/2W. resistors meet applicable MIL-R-11 specifications, 50 ohms to 50 megs. Capacitors up to .01 mmf.

Write for Group Y bulletins.

*Trade Mark



VARIABLE RESISTORS

1/4W. Linear Motion, wirewound 100 to 20K ohms and composition 10K to 2.5 meg. .250″ x .325″ x 1.250″.

1/10W. Microminiature, 0.286″ diam: **Ultraminiature**, 0.502″ diam; **Subminiature**, 5/8″ diam; 500 ohms to 10 megs. **1/4W. and 1/2W. Subminiature**—For instruments and military. 43/64″ diam. 500 ohms to 2.5 megs.

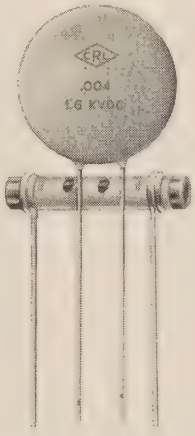
1/4W. Multiple Miniature—Up to 4 variable and 9 fixed resistors on a 3/4″ x 2-1/4″ steatite plate. 1000 ohms to 5 megs.

1/2W. Standard—For radio, TV. Single, Twin or dual-concentric. 15/16″ diam. 250 ohms to 10 megs.

1-1/2W. Wirewound—for military and instruments. 11/16″ diam., 5/16″ deep. 4 ohms to 30K ohms.

2-5W. Wirewound—For instruments and TV. Single or dual-concentric. 1-5/32″ diam. 1 ohm thru 100K ohms. Also available as 20 watt audio L and Bridged T Pad attenuators.

Write for Group B bulletins.



CERAMIC CAPACITORS

Ultraminiature—3 to 10VDC, 0.22—2.2 mfd.—for low power factor transistor applications.

Temperature compensating—Discs, tubulars, 150 v to 6,000 VDCW. 1 mmf.—0.1 mf. Capacitance +100 to —5250 ppm.

Bypass—Coupling—Discs, tubulars, 150 v to 6,000 VDCW, 1 mmf.—0.1 mf.

High Voltage—High Accuracy—High Voltage types, up to 30,000 VDCW, High Accuracy types, ± 1% tolerance, 500 VDCW, up to 2,500 mmf.

Trimmer—Tubular or flat. Meet MIL-C-81A specifications. 1 mmf. to 400 mmf. 500 VDCW.

Feed-thru—10—5000 mmf., 500—1,500 VDCW, bushing, shoulder, ring, eyelet, resistor-capacitor combinations.

Specialties—Stand-off, button-shape, potted, other capacitors.

Write for Group D bulletins.

ENGINEERED CERAMICS

High alumina—85%, 95%, 99%—for high frequency, high temperature applications close tolerance (±.00025″) designs. L6A Jan-I-10 grade.

Grade Jan-I-10-L5A steatite, Grade L2A Corderite, and Grade L2A Electrical Porcelain. For applications where high dielectric and compressive strength, high dimensional stability, low loss and low power factor are required, there is a CENTRALAB ceramic material for the job.

CENTRALAB also specializes in metalizing of ceramics, for hermetic seals or mechanical attachment of other ceramic or metal parts.

Write for Group X bulletins.

Centralab.

THE ELECTRONICS DIVISION OF GLOBE-UNION INC.
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In Canada: Centralab Canada Ltd., P. O. Box 400, Ajax, Ontario

G-6140

ELECTRONIC SWITCHES • VARIABLE RESISTORS • CERAMIC CAPACITORS • PACKAGED ELECTRONIC CIRCUITS • ENGINEERED CERAMICS

PHYSICISTS AND ENGINEERS

Goodrich-High Voltage Astronautics, a jointly owned subsidiary of High Voltage Engineering Corporation and the B. F. Goodrich Company is a dynamic, new company doing research and development work in space technology. Analytical and experimental programs in advanced ion generation, particle beam optics, electrostatics, and solid state devices are immediately available for scientists and engineers with demonstrated ability at all degree levels. We offer:

- A Dominant Technological Position
- A Vigorous Scientific Climate
- A Select Professional Staff
- Expanding Research Facilities
- Outstanding Opportunities for Personal Leadership
- Small Company Atmosphere with Strong Financial Support

ELECTROSTATICS and POWER CONVERSION

Power supplies for space, electrostatic generation, electric field problems, high voltage insulation, electric and magnetic energy storage techniques, spinning cathode development, thermionic power generation, high speed rotation in vacuum.

ION DEVICES, PLASMA PHYSICS

Ion sources and engines for critical applications in space, power supply requirements for these devices including design and execution of experiments leading to practicable systems, experimental studies of plasma phenomena in arc type ion generators and neutralized beam dynamics.

SOLID STATE DEVICES

Electron and/or ion beam techniques for radical new approaches to information storage and microcircuitry. Solid state measurements to initiate programs in organic semiconductors and energy storage in insulators.

ghva

Goodrich-High Voltage Astronautics, Inc.

BURLINGTON, MASS.
(12 Miles North of Boston)

For further information concerning our current openings please write in confidence to: Mr. Louis J. Ennis, Assistant Personnel Manager, P. O. Box 98, Burlington, Massachusetts.

'An equal opportunity employer'

Check Inquiry Form on Page 131, Part 1

applied to a make-and-break contact device, use a current-limiting resistor in conjunction with the capacitor to prevent large instantaneous energy changes that would eventually cause contact failure. Prefer non-inductive resistors.

✔ *Filters* are sometimes used as suppressors for conducted interference. They are generally classified by their configuration as L-, T-, or Pi-type, by their circuit function as power-line, harmonic-suppression, or rectifier-output filters, or by their bandpass as high-pass, low-pass, or bandpass filters.

- Do not use filters where feedthrough or bypass capacitors will be as effective.
- Isolate output leads from input leads.
- Do not physically place filters parallel to interference-carrying lines of components, particularly other coils.
- Connect bypass filters to ground with the shortest possible low-impedance lead.
- Shield filter input leads and output leads with a grounded shield.
- Use a capacitive input filter in low-current applications.
- Use filters with distributed constants for frequencies above 70-80 mc.

SWITCHES

✔ Keep in mind that, when interrupting inductive circuits, switches may create arcs. These arcs will cause transfer of material from one contact to the other, resulting in peaks and craters in the contacts.

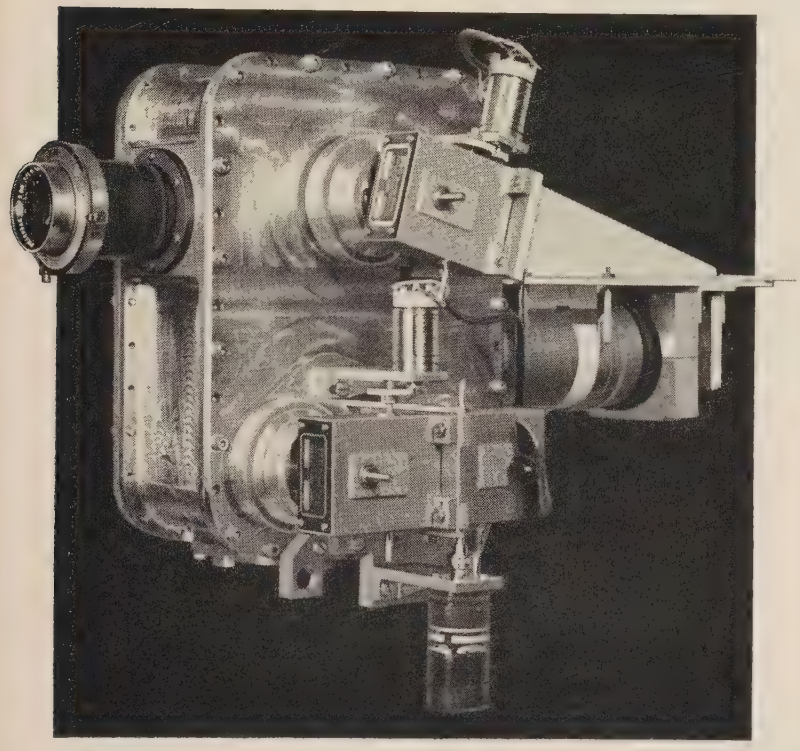
✔ Arcing can also be caused by contact bounce, an uncontrolled making and breaking of contact. If the operating times of the circuits controlled by the switch are considerably longer than the intervals between bounces, bounce must be kept to a minimum. Otherwise, electrical noise will be produced in the circuit in which bounce occurs or in an associated circuit.

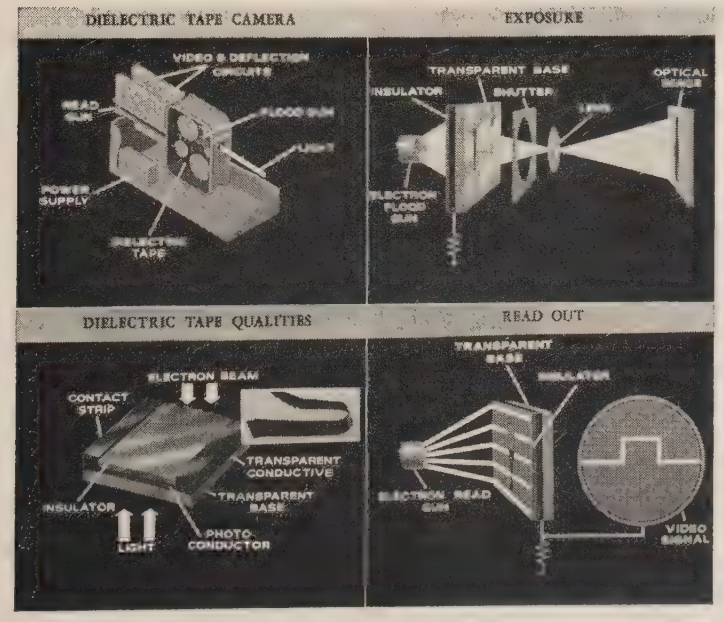
✔ When using precision switches, consider these points:

- *Repeat Accuracy:* For many control applications, repeat accuracy is important. Accuracies are available to 0.0001 in. However, drift occurs with temperature variation and use. Specify repeatability in 100,000 successive operations. To avoid contact sticking in precise applications, only light electrical loading is permissible.
- *Differential Motion:* Where a switch is used in conjunction with pressure and temperature sensing elements for control purposes, a close differential motion is required between the operate and release positions. Differential motions of the order of 0.0002 in. are available.
- *Operating Force:* This force depends on spring stiffness and contact separation. A uniform force with a close differential between operate and release is important.
- *Load Factors:* Heavy loads cause contact stickiness and reduced repeatability. Contact materials must be related to load requirements, both in capacity at high power levels and low contact resistance at milliwatt power levels. Operating forces are higher in heavy load switches.
- *Life:* Mechanical life is determined by the fatigue characteristics of the spring. Wide contact spacing in high-voltage units means more spring motion, greater fatigue stresses, and shorter life. Electrical life depends on proper operation within the contact ratings. Inductive

PHOTO-DIELECTRIC TAPE CAMERA SYSTEM

. . . a major advance in space image-sensing





The development of photo-dielectric tape permits the design of a totally new image-sensing system for utilization in satellites and space vehicles. A prototype camera for use with this tape has already been operated and tested. This system, one of the first developed primarily for use in space, offers a number of advantages over existing photographic and television techniques.

Operating on the principle of storing an optical image by converting it to an electronic charge pattern, the photo-dielectric system has inherently high resolution since the picture charge pattern is read out directly as a video signal by an electron beam Moreover, it offers real promise of providing response in various parts of the radiation spectrum in addition to the visible including infrared and ultraviolet with sensitivity better than standard photographic techniques.

Readout is accomplished by use of a finely focused electron beam which scans the charge pattern. It is then converted directly to a video signal for transmission to the ground. Readout can be accomplished at different speeds to compensate for various power and band-width requirements dictated by the nature of the space mission.

The flexibility of the system permits readout of the same image numerous times, if desired, by ground control. In the laboratory, the same image has been read out up to 100 times without serious degradation of quality. Yet, the image is erased completely, with no trace of "sticking," as the tape is flooded with electrons prior to exposure. Transistorization of the package results in minimum weight and low power requirements.

Since a high vacuum is essential to the operation of a photo-dielectric tape camera system, it is "at home" in the harsh environment of space. Also, dielectric tape is virtually unaffected by radiation thereby eliminating this hazard to ordinary photographic film. It is also reusable and serves as its own storage medium for remote picture-taking sequences.

To find out how RCA's new photo-dielectric tape camera developments can fill your requirements for space image-sensing systems, write to the Manager, Marketing, Astro-Electronics Division, Defense Electronic Products, Radio Corporation of America, Princeton, New Jersey.

And for a challenging, rewarding career in electro-optical systems development, apply to the Employment Manager, RCA Space Center, Princeton, New Jersey. All qualified candidates are considered regardless of race, creed, color or national origin.

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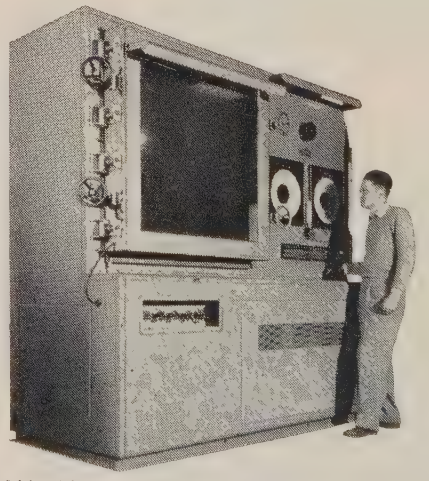
Our engineers work closely with you to develop a motor for your exact needs. Fast delivery on both special and production motors. Phone or write Eicor, Oglesby, Illinois. Dept. U-12.



This altitude chamber is used for environmental testing of airborne equipment. It simulates altitudes up to 80,000 ft with temperature control to —67° F.

INDIANA GENERAL
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HIGH-RELIABILITY ROTATING EQUIPMENT

loads, lamp and motor loads, contact source, and welding of contacts are factors governing contact life.

In thermal switches, two separate aspects of the temperature-control problem must be considered: proper installation of the thermostat within a well-designed control system, and proper design of the heat system and the relationship of the thermostat to it. In any typical thermal-control application, the total variation of temperature about the desired value is larger than the thermostat differential as a result of "hunting." The amount of this temperature variation about the mean value is determined by heater characteristics, the process being controlled, and the controlling thermostat. Transfer of heat from the source to the process should be as effective as possible. If the temperature of a metal unit is being controlled, cast the heater into the block itself. If this is not possible, use an indirect heater in firm contact with as large an area as possible. In the case of liquids, placing the thermostat only a few inches above the heaters will give better control.

For mercury switches, the following points are important:

- When exceptionally high reliability and long service life is required, use a hard glass with a quartz liner mercury switch.
- For very frequent switch operation in motor, make, break, load, and load-reversal circuits, use a mercury switch with a hard glass that has a porcelain liner fused on the body.
- For normal load, load-reversal, and motor circuits, use a mercury switch made of plain glass with a liner in the form of a ceramic insert.
- For auxiliary or control circuits used as an open-circuit, load, or load-reversal switch, or as an occasionally-used motor switch, use a mercury switch made of plain glass.

SYNCHROS

Corrosion is the principal cause of trouble, with temperature an additional problem. If moisture can enter the windings, it may cause insulation breakdown between the windings or between winding and

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frame. The air gap between rotor and stator is relatively small, and failure will result if corrosion settles on the outside of the rotor or the inner surface of the stator. Corrosion on the slip rings or brushes will prevent satisfactory operation. Another cause of failure is improper lubrication of the ball bearings.

TIMERS

- Use a motor-driven timer operated from the supply voltage.
- Use a digital readout system.
- For 115 V AC operation, the synchronous motor is the most accurate. DC motor-driven timers are not as accurate as the AC types.

THERMISTORS

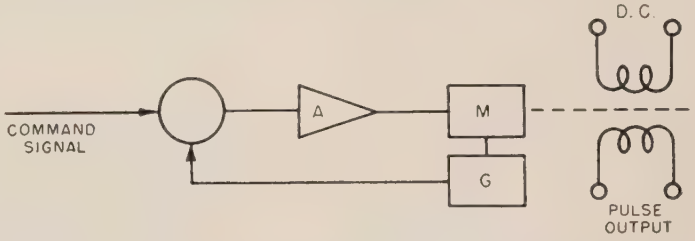
- Thermistors are essentially thermal-sensitive resistors composed of a semiconductor material whose resistance varies from that of a conductor to that of an insulator. Stresses affecting the failure rate of thermistors are temperature and wattage.

TRANSFORMERS

- Where applicable, use Mil-T-27A transformers as follows:
  - *Grade 1* for maximum reliability, life, or operation under all climatic conditions.
  - *Grade 2* for flame resistance in addition to the requirements for Grade 1.
  - *Grade 3* where little or no protection from climatic conditions is required.
  - *Grade 4* for extreme resistance to shock and vibration, in addition to the requirements for Grade 1.
  - *Grade 5* for resistance to flame, in addition to the requirements for Grades I and 4.
- A type designation might look like "TFIRXO1FB004" and means: TF, component; I, grade; R, class; X, life expectancy; 01, family; FB, case and mounting dimensions; 004, identification number.
- To reduce surge voltages caused by the interwinding capacity of the transformer, use capacitors connected directly across the secondary transformer terminals.
- Avoid excessive primary voltage. It may lead to immediate puncture of the insulation if the over-

CASE NO. 1: **To provide output speed for radar tracking**
To provide integral information for digital computors

SOLUTION: An in-line assembly containing a servomotor, temperature compensated rate generator, gear train and digital pulse generator providing 8 pulses per revolution. A separate miniaturized servo amplifier completes the package.



An input voltage is compared with the generator output voltage in a feedback loop. This arrangement provides accurate speed control of the motor — and the output shaft. Output of the pulse generator represents the time integral of the input voltage. Accuracy is held to 0.1%.

FOR YOU: A design staff and manufacturing skill, experienced through hundreds of similar cases, to solve your own servo problems — swiftly and economically.

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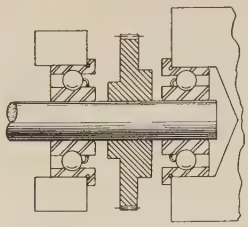
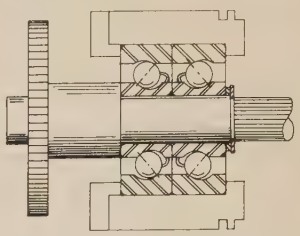
No. 3

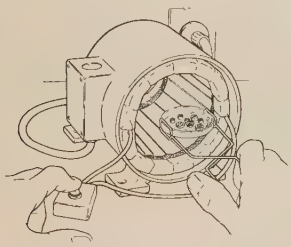
ideas you can use in working with bearings



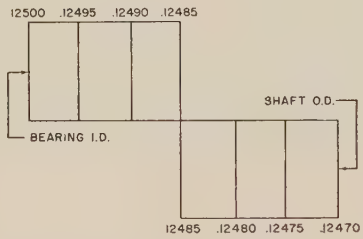
The use of flanged bearings can reduce expense in servomechanism gearing, especially where plate or cantilever construction is involved. The flange eliminates the need for bearing retainer plates and also makes it possible to blind depth bore to non-critical depths. The blind hole can be used as a lubricant reservoir to retain grease.



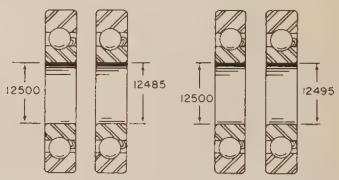
The output shaft bearings in gear heads are usually preloaded to reduce backlash. Pairs of bearings, preloaded to a specific value by the bearing manufacturer, offer two advantages. Variation in preloading during assembly is eliminated which means more consistent torque and end shake values from unit to unit. Secondly, assembly time is reduced. Where required, the advantages of preloaded bearings can justify their additional cost.



A bearing which has become magnetized will attract stray metallic particles which can work their way on to raceways or balls with disastrous effects on bearing performance. Although all New Hampshire bearings are carefully demagnetized before final washing and packaging, it is possible for them to be re-magnetized during shipment if they are placed in strong magnetic fields. A good precaution is to perform final demagnetization before installing bearings in their final assemblies.



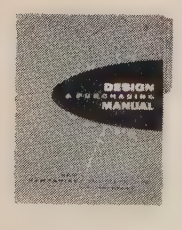
Interference fitting tighter than line to line is not recommended by New Hampshire for the majority of applications. The block diagram above shows this fit achieved by coded selection. The bearing I.D. is represented by the top blocks and the shaft O.D. by the lower blocks. The bearing I.D. represents a tolerance of .00015″ with a similar tolerance for the shaft. A resulting fit of line to line to .0003″ loose is shown.



ABEC CLASS 7 BEARINGS WITH STANDARD BORE TOLERANCES OF .00015" AT EXTREMES OF BORE TOLERANCE

ABEC CLASS 7 BEARINGS WITH BORES CODED IN .000050" INCREMENTS AT EXTREMES OF BORE TOLERANCE.

In high accuracy designs where bearings must be as close together as possible (e.g. bevel gear differentials) shaft to inner race fit is vitally important to assure as much radial stability as possible under these conditions. Even two ABEC Class 7 bearings would not provide a sufficiently precise fit should their bores be at the extremes of tolerance (.00015″). However, bearings may be specified with bores coded in .000050″ increments.



150-page Design and Purchasing Manual is the most comprehensive treatise on miniature and instrument ball bearings ever published. Qualified design and specifications engineers, and procurement specialists, are welcome to a copy.

NHBB FLANGED RETAINER BEARINGS

BORE	O.D.	WIDTH	BEARING NUMBER	FLANGE DIAMETER	FLANGE WIDTH	RADIUS	C RATING
.0469	.1562	.0625	SFR0	.203	.013	.005	19
.0550	.1875	.0781	SFR1	.234	.023	.005	28
.0781	.2500	.0937	SFR1-4	.296	.023	.006	39
.0937	.1875	.0625	SFR133	.234	.018	.005	21
.0937	.3125	.1094	SFR1-5	.359	.023	.006	64
.1250	.2500	.0937	SFR144	.296	.023	.005	36
.1250	.3125	.1094	SFR2-5	.359	.023	.006	66
.1250	.3750	.1094	SFR2-6	.422	.023	.006	66
.1250	.3750	.1562	SFR2	.440	.030	.012	73
.1562	.3125	.1094	SFR155	.359	.023	.005	35
.1875	.3125	.1094	SFR156	.359	.023	.005	35
.1875	.3750	.1250	SFR166	.422	.023	.008	82
.1875	.5000	.1960	SFR3	.565	.042	.012	137
.2500	.3750	.1250	SFR168	.422	.023	.008	44
.2500	.5000	.1250	SFR188	.547	.023	.010	120
.2500	.6250	.1960	SFR4	.690	.042	.012	170
.3125	.5000	.1562	SFR1810	.547	.031	.009	60

NEW HAMPSHIRE BALL BEARINGS, INC.
PETERBOROUGH, N. H.

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voltage is high enough or to premature breakdown if the overvoltage is moderate (about 20 per cent above nominal voltage).

Avoid excessive secondary currents. They cause overheating of the transformer, with a consequent weakening of the dielectric strength of the insulation, and open or short-circuited windings, or containers misshapen or broken as a result of expansion of potting or filling compound.

Be sure frequencies are neither below nor above the design limits. Those below the lower limit will cause low reactance and higher-than-design currents; those above the upper limit will result in higher core losses. In either event, the temperature of the transformer will be higher than the nominal temperature rise, and the dielectric strength of the insulation will be decreased because of the inverse relation of dielectric strength to temperature.

Consider the effect of corona on transformers. At points of high potential stress, corona accelerates insulation aging by liberating ozone and increasing temperatures. It creates weak spots in the insulation that eventually lead to insulation breakdown.

TRANSISTORS

Junction breakdown voltages and junction temperature appear to be the two chief concerns of the designer if he is to obtain high reliability in transistor circuits. Voltage transients are particularly harmful to transistors. Circuit designers must consider transistor voltage ratings not only during the design of individual circuits but also for protection against power line transients.

Transistor failure rates are generally related to junction temperature resulting from either ambient or operating conditions. Hence, failure rates may be expected to increase or decrease in accordance with junction temperature.

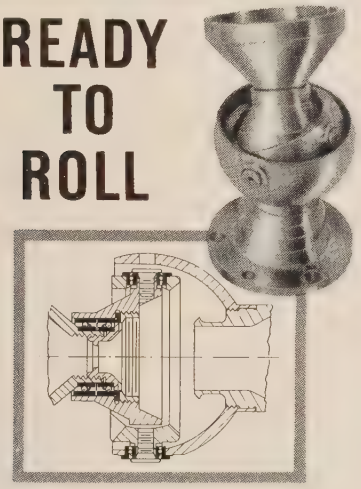
Until better information becomes available on failure modes, failure rates and failure patterns of the many classes of semiconductor devices, derating should be used.

For general transistor use:

- Design the circuit to perform with each parameter at the greatest extremes likely to be met in operation.
- Steer the transistor toward

Instrument sub-assemblies complete with precision-fitted miniature or instrument ball bearings

READY TO ROLL



If you have a problem making or obtaining some of the proper components for instrument bearing sub-assemblies — or if you have trouble fitting them together with the required precision — you should investigate the services of the Rotassembly Division at New Hampshire.

In this separate facility, assemblies including bearings, shafts, housings and pulleys are produced to your designs, to New Hampshire precision standards and shipped to you inspected, tested and ready to install.

Manufacture is restricted to mechanical units in which the correct installation and performance of bearings are important and critical elements of the assembled unit. We are not manufacturers of or qualified to produce gears, gear trains, gear boxes, motors or electrical components.

For more complete information, write for Rotassembly Bulletin.

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SIZE 8 SYNCHROPOT* first *In-Line Assembly* of synchro and potentiometer!

Industry's first *in-line-assembled* synchro and potentiometer combination —that's the unique SYNCHROPOT! A single turn linear potentiometer is tied to a size 8 synchro transmitter, differential, resolver, or control transformer to provide a high degree of system flexibility. Unitized package means easy installation, space-saving convenience. Direct coupling between synchro rotor and wiper arm eliminates gears and backlash. Ideal for conversion of three wire synchro data into linear ac or dc data, utilizing the potentiometer with a control transformer in a conventional feedback loop.

Potentiometer resistance values from 100Ω to 10,000Ω.

Call or write your nearest Daystrom Field Engineer for information specific to your application.

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dependence on the most stable and predictable properties.

• Consider that derating improves reliability in several ways. Reduced stresses on the transistor reduce reversible changes in device parameters. Lower operating ambient temperatures, lower power dissipation, and improved heat sinks result in lower maximum operating junction temperatures, thereby reducing reversible excursions in temperature-sensitive parameters. Lower operating voltages result in lower values of leakage current, so that I_{co} is not only less but approaches the more predictable saturation current level.

• Pay particular attention to anticipated values of supply voltages and temperatures. Check also the possibility of voltage transients. A number of transistor manufacturers suggest that maximum peak voltages not exceed 75 per cent of any transistor voltage rating.

• Circuits should be designed to tolerate changes in transistor characteristics due to temperature variation and "aging". Some equipment manufacturers suggest designing circuits to provide for changes 30-50 per cent lower than the life test and point limits for h_{fe} (measured under standard conditions) and for changes 100 per cent higher than the life test end point limits for I_{cbo} (measured under maximum rated temperature and voltage conditions).

• When a transistor type is to be used in several different circuit applications, the specification must be comprehensive enough to cover each of these areas.

✔ For audio voltage amplifiers:

• Where a high input impedance audio amplifier is required, use a common-emitter transistor stage with an unbypassed emitter resistor. This technique generally raises the input impedance to tolerable levels, with a slight decrease in gain caused by degeneration. The decrease in gain may be compensated by a high-gain transistor or by additional stages in cascade.

• For the common-emitter transistor amplifier, select a base bias resistor whose value is large compared with the input impedance and small compared with the emitter bias resistance. The amplifier stage must be stable and must not load the input circuit.

• For AF power amplifiers, use

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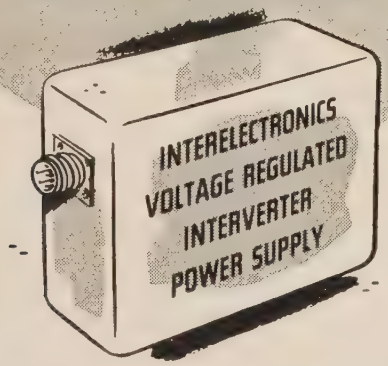

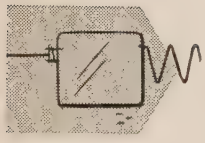

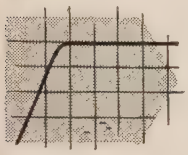

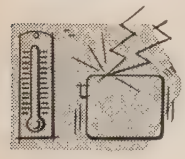

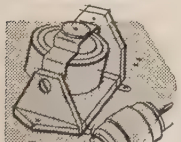

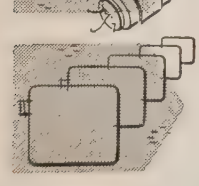

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Ultra-reliable in operation (over 260,000 logged hours), no moving parts, unharmed by shorting output or reversing input polarity. High conversion efficiency (to 92%, including voltage regulation by Interelectronics patented reflex high-efficiency magnetic amplifier circuitry.)

Light weight (to 6 watts/oz.), compact (to 8 watts/cu. in.), low ripple (to 0.01 mv. p-p), excellent voltage regulation (to 0.1%), precise frequency control (to 0.2% with Interelectronics extreme environment magnetostrictive standards or to 0.0001% with fork or piezoelectric standards.)

Complies with MIL specs. for shock (100G 11 mlsc.), acceleration (100G 15 min.), vibration (100G 5 to 5,000 cps.), temperature (to 150 degrees C), RF noise (I-26600).

AC single and polyphase units supply sine waveform output (to 2% harmonics), will deliver up to ten times rated line current into a short circuit or actuate MIL type magnetic circuit breakers or fuses, will start gyros and motors with starting current surges up to ten times normal operating line current.

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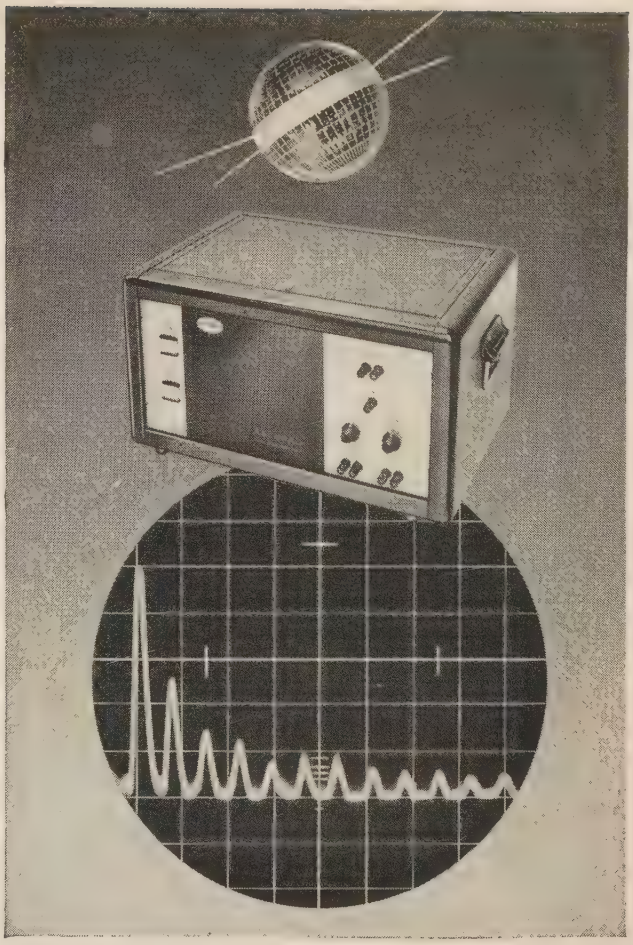

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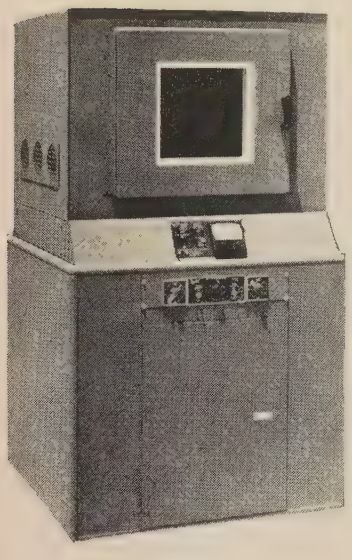

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Class B complementary-symmetry output circuits where feasible to eliminate the output transformer. Make sure that output stage current does not produce feedback currents to the local oscillator gain-controlled RF and IF stages or low-level audio stages. Such feedback can often be prevented only by brute-force filtering in emitter return and base bias bypasses.

✓ For switching circuits:

• In analyzing transistor switching circuits, consider the rise and fall time separately from the hole storage time.

• Use saturation and reverse drive to decrease rise and fall time in switching circuits. There will be a corresponding decrease in power gain. To decrease rise time, use an input current high enough to drive the transistor well into saturation. To decrease fall time further, increase the reverse-drive base current or drive the input from a low impedance source. To optimize the fall time, apply reverse current to the input. The discharge of a base capacitor in an RC-coupled circuit will apply a reverse (positive) voltage spike to the base.

• Eliminate hole storage with a switching circuit design that prevents the transistor from being saturated. Since this technique requires considerably more compo-

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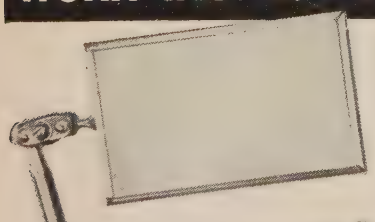

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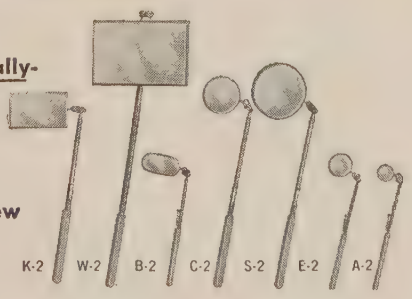

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Reset: Automatically resets when acceleration is removed
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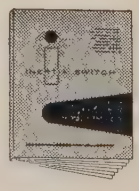

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nents, reduce the transistor's tendency to store holes by maximizing the alpha-cutoff frequency while minimizing base resistance for a given current amplification factor. Alternatively, drive the base from a low-impedance source with reverse input bias. This latter method improves the hole-storage characteristic. (Work on semiconductor materials with low hole storage capacity has been most successful to date with silicon alloy transistors.)

• To minimize the effects of variation of the saturation and base-to-emitter junction voltages, use a supply voltage sufficient to make $(V_{sat}+V_{ib})/V_{cc}$ approach zero.

• In silicon transistors, the effect of fi_{cbo} on circuit stability is negligible up to temperatures of 140 deg C. In germanium transistors, the effects of the DC collector cutoff current must be taken into account above 40 deg C.

• Current gain (h_{fe}) increases with temperature rise. The low h_{fe} at room temperatures limits the stability and performance of switching circuits, whose stability actually increases with temperature. Therefore, the silicon transistor, which can be safely operated at up to 140 deg C, is recommended for switching applications.

• Use microalloy transistors for high-speed, low-power switching, and mesa transistors for high-speed, high-power switching.

• For greatest operational stability, use the emitter-follower coupled circuit. For highest switching speed, use an emitter-follower coupled flip-flop.

• The RC-coupled flip-flop is the second-fastest circuit. Non-saturating versions of the emitter-follower and RC-coupled circuits are faster than saturating counterparts because of the elimination of hole-storage delay time.

• Where static stability is more important than speed of operation, use series base resistors in digital computer transistorized logic circuits.

• When using silicon transistors, check out circuits at temperatures between room temperature and 140 deg C, since silicon transistors show higher gain at higher

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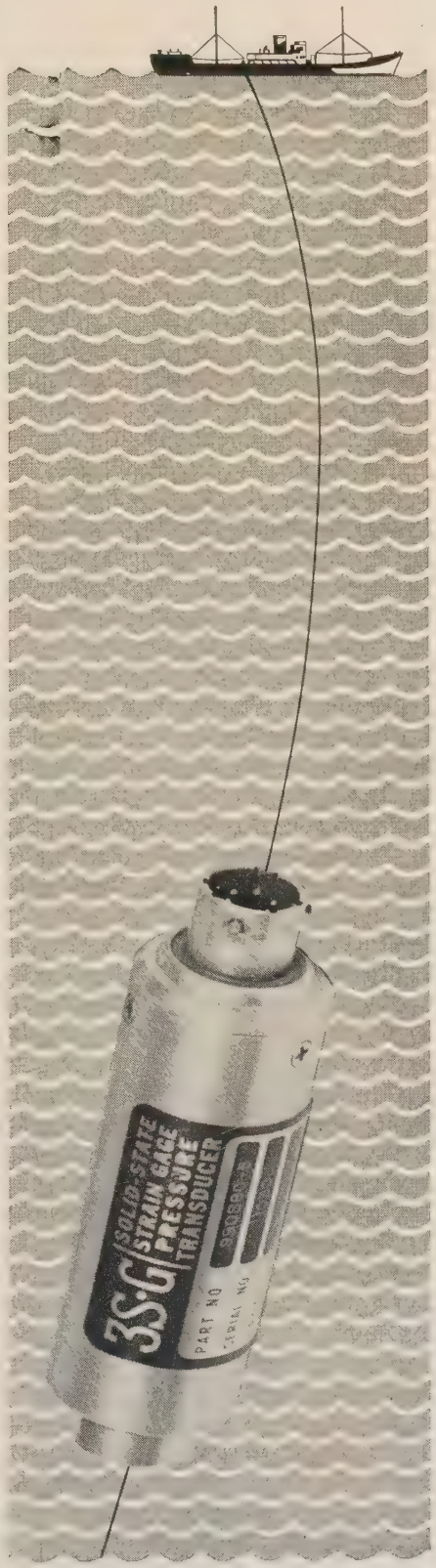
For more information about the 3S-G silicon-semiconductor strain-gage pressure transducer, write Dept. 51 SA.



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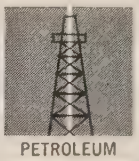
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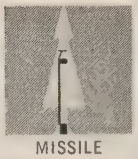
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temperatures with no sacrifice in operating speed.

✓ In DC-DC converter applications:

- Where efficiency is not a factor, single-transistor switch types are suitable for both voltage power supplies.
- Two transistor push-pull switch types are preferable for high-efficiency operation.
- Designers of push-pull converters should aim at square-wave production by the inverter section. The more perfect the square wave, the more efficient the power conversion.
- Transformers must couple the square wave generated by the inverter without introducing distortion.
- Transformers must have a low magnetizing current characteristic.
- Transformers must saturate at the level of current to be drawn from them in normal use.
- When it is difficult to get transformer saturation at the required output current, two transformers can be used. One transformer acts as a feedback resaturate, the other as the output transformer. The two-transformer arrangement is recommended if output powers above 50 W are involved. The two-transformer technique is not recommended where power output is below 20 W.
- The saturation of the special feedback transformer must be as independent of the load as possible.
- Transistors must have very low saturation resistance and low leakage current.
- Use base resistors for switching in order to limit base current.
- Because DC to DC converters present heat-dissipation problems, use silicon transistors instead of germanium types where possible.

VARACTORS

✓ Diode capacitance is not fixed, but is a function of applied voltage. The plates of a varactor diode are not physically fixed, but may be considered as the P- and N-regions, separated by a space charge region. Diode capacitance under reversed bias conditions is analogous to that of a fixed capacitor and may be expressed as:

$$C = EA/X,$$

where C is capacitance; A, area of junction; E, dielectric permittivity of the semiconductor material; and X, distance between N- and P-regions. The value of X in this equation depends on the applied reverse voltage and is determined by:

$$X = K^n V,$$

where n is two for an abrupt junction and three for a graded junction; V, applied reverse voltage; and K depends upon resistivity.

The frequency at which varactor capacitance is measured is usually included in the diode spec. A close approximation is that switching diode capacitance is independent of frequency up to several hundred megacycles. Above this frequency, additional factors, such as the effects of lead inductance of the diode package, become important.

✓ Since the capacitance of a reverse biased diode varies with applied voltage, varactors are useful for application in some tuning circuits.

When varactors are used in

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linear circuits, the voltage excursion should be kept relatively small compared with the bias voltage in order to prevent non-linear distortion. Its non-linear voltage-capacitance characteristic makes varactors useful for low-noise parametric, harmonic generation, modulation, and other special applications.

WAVEGUIDES

✓ Use waveguides for minimum attenuation and maximum power. Where bandwidth is of primary concern, use coaxial lines. They can span four to six decades of frequency with no difficulty and offer considerable savings in size and weight at frequencies below 1000 mc, where waveguide dimensions become prohibitive.

✓ Do not operate waveguides too close to their cutoff limits at high powers. Select a guide size so that the desired frequency will be close to midband.

✓ Use a nominal number of waveguide couplings—good preformed bends or flexible assemblies where possible.

✓ A certain amount of distortion of waveguide flanges is inevitable when a flange is brazed to the waveguide tube. On "precision" contact flanges and cover flanges, this distortion is held to a minimum by letting the tubing project through the flange when it is brazed on and later machining off the excess tubing and the face of the flange to meet the flatness and angularity requirements. On "precision" flanges, the assembly holes are drilled after brazing. For these flanges and cover flanges, the designer should specify the minimum thickness of the flange for the finished assembly.

For choke flanges, the tolerances on the dimensions of the choke ditch and similar features must be relaxed somewhat from those shown on the Government drawings of the machined part.

✓ The exterior of waveguide sections should be finished in accordance with project requirements.

✓ Usually, no attempt is made to provide a protective finish on the inside of waveguide sections, except in the case of brass pieces for Bu Weps projects. Most contracts with this agency require a zinc-chromate primer (Mil-P-8585, color Y) on such pieces.

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THERMAL COEFFICIENT OF SENSITIVITY:	0.02% /°F.
THERMAL ZERO SHIFT:	0.01% /°F. of full scale output.
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POWER REQUIREMENTS:	30 ma at 28 V DC ±10%.
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Reliability Specs, Standards, and Bulletins

Compiled by SPACE/AERONAUTICS from a variety of sources, this list provides a quick, alphabetical reference to general reliability areas and their applicable documents.

- *Assurance program:* Mil-R-25717C.
- *Data:* Mil-D-9310, Mil-D-9412C.
- *Demonstration requirements:* Mil-R-26667A.
- *Design*—equipment and systems: Mil-R-22256.
- *Development*—systems and subsystems: Mil-R-26484.
- *Enclosures:* Mil-Std-108C, Mil-C-172C-1D, Mil-E-2036C (1).
- *Environment factors:* USAF Spec Bltn 106, USAF Spec Bltn 115, ANC Bltn 22, Mil-Std-210A, Mil-T-152A.
- *Ground checkout equipment:* Mil-R-27173.
- *Human factors:* WADC-TR-56-488, Mil-M-25946, Mil-D-26207.
- *Installation:* Mil-I-8700, Mil-E-0025366B.
- *Interference:* Mil-I-006051B, Mil-I-6181B, Mil-I-26600 (1), PD-R-186.
- *Maintainability:* Mil-M-26512.
- *Military electrical equipment:* Mil-Std-441.
- *Missiles and space systems:* AFBM 58-10.
- *Monitoring:* USAF Spec Bltn 506, ACGMR; Report or Air Force Letter AFL 84-1.
- *Organization:* USAF Spec Bltn 510.
- *Preservation and packaging:* Mil-P-116C (1), USAF Spec Bltn 56AF, Mil-P-9024B, MQ PPP-1.
- *Production electronic equipment:* Mil-R-19610.
- *Provisioning:* Mil-B-5005A (2), DOD Instr 3232.7, MCP-71-673, PP-SIG-SE-IA, SAR-400, SAR-398, Mil-E-173620.

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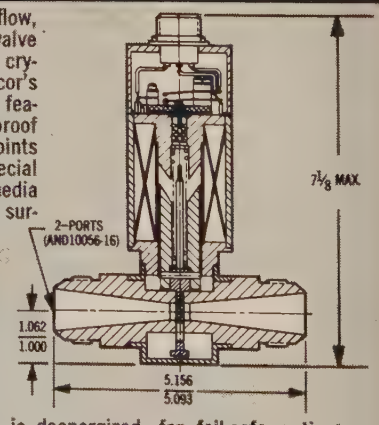

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• *Quality control:* Mil-Q-9858, PD-Q-501, Mil-Q-19614.

• *Reliability guides:* Agree Report—Reliability of Military Electronic Equipment. PB-121839—NEL Reliability Design Handbook. Woodson — Human Engineering Guide for Equipment Design, Univ of Calif Press. NEL—Suggestions for Designers of Electronic Equipment. AD 148556 (Astia)—Philosophy and Guidelines-Prediction on Ground Electronic Equipment. ANA Bulletin 444—Aircraft Electronic Equipment Design Criteria. Mil-E-5400D — General Specification for Aircraft Electronic Equipment. Mil-E-16400C — General Specification for Naval Electronic Equipment. Mil-E-8189B—General Specification for Guided Missile Electronic Equipment. Mil-E-4158B (1) — General Specification for Ground Electronic Equipment. Mil-W-9411A (1)—General Specification for Aeronautical Weapons Systems. Mil-E-19100A — General Specification for Shipboard Training Electronic Equipment. Mil-E-19600A—General Specification for Aircraft Electronic Modules.

• *Reliability requirements:* Mil-R-26667A (USAF)—Reliability and Longevity Requirements, Electronic Equipment, General Specifications for; June '59. Mil-R-26674 (USAF) — Reliability Requirements for Weapon Systems; June '59 (to be superseded by Mil-R-27542).

• *Sampling:* Mil-Std-105, Mil-Std-414, DOD-HDBK-M-106.

• *Test equipment:* Mil-T-21200A, Mil-T-8191 (1), Mil-T-945A (2), Mil-Std-415A, Mil-T-18306A.

• *Test Methods:* Mil-E-5272C, Mil-T-5422E, Mil-E-4970A, Mil-Std-202A, Mil-T-18303, Mil-T-4807A.

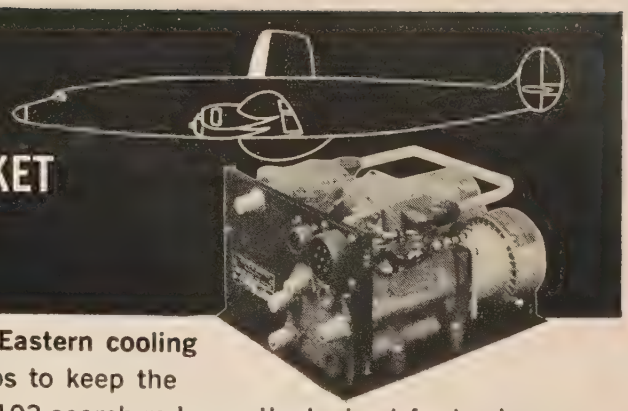
• *Test reports:* Mil-T-9107 (1).

• *Training:* Mil-T-4857B, Mil-T-4860C, Mil-T-9344, Mil-I-26036, Mil-T-26046, Mil-D-26239.

• *Weapon system:* Mil-R-26674.

• *Wiring:* Mil-W-5088B, PD-E-53, Mil-W-008160C, Mil-T-713A (2).

ABOARD A RADAR PICKET PLANE



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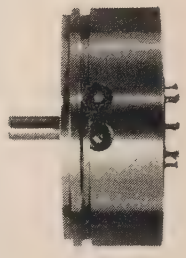

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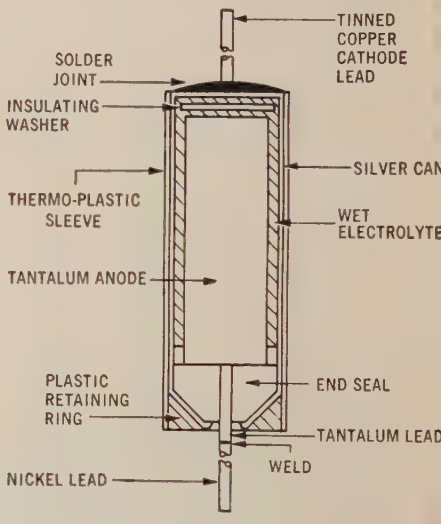
NEW

STRAIGHT WALL TANTALUM CAPACITOR CAN'T LEAK

Meets MIL C 3965-B, Style CL-64, CL-65.

A new space-saving approach to the design of wet tantalum capacitors ends mounting problems encountered with flanged types and yet will not leak.



ITT's compact, sintered slug tantalum capacitor features a wedge-shaped seal held under compression by an epoxy retainer ring formulated for thermal characteristics inverse to those of silver. Ordinary, straight-wall capacitors leak along the lead when elastomer compression is reduced as the silver can expands. Not so with the new ITT design!

This new, compact capacitor conforms to specifications MIL C 3965-B, Style CL-64, CL-65 and provides both the compactness and rugged reliability required in missile, airborne and mobile equipment. For details, write today requesting Bulletin No. 610.

ITT

CAPACITOR DEPARTMENT
COMPONENTS DIVISION
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION, PALO ALTO, CALIFORNIA

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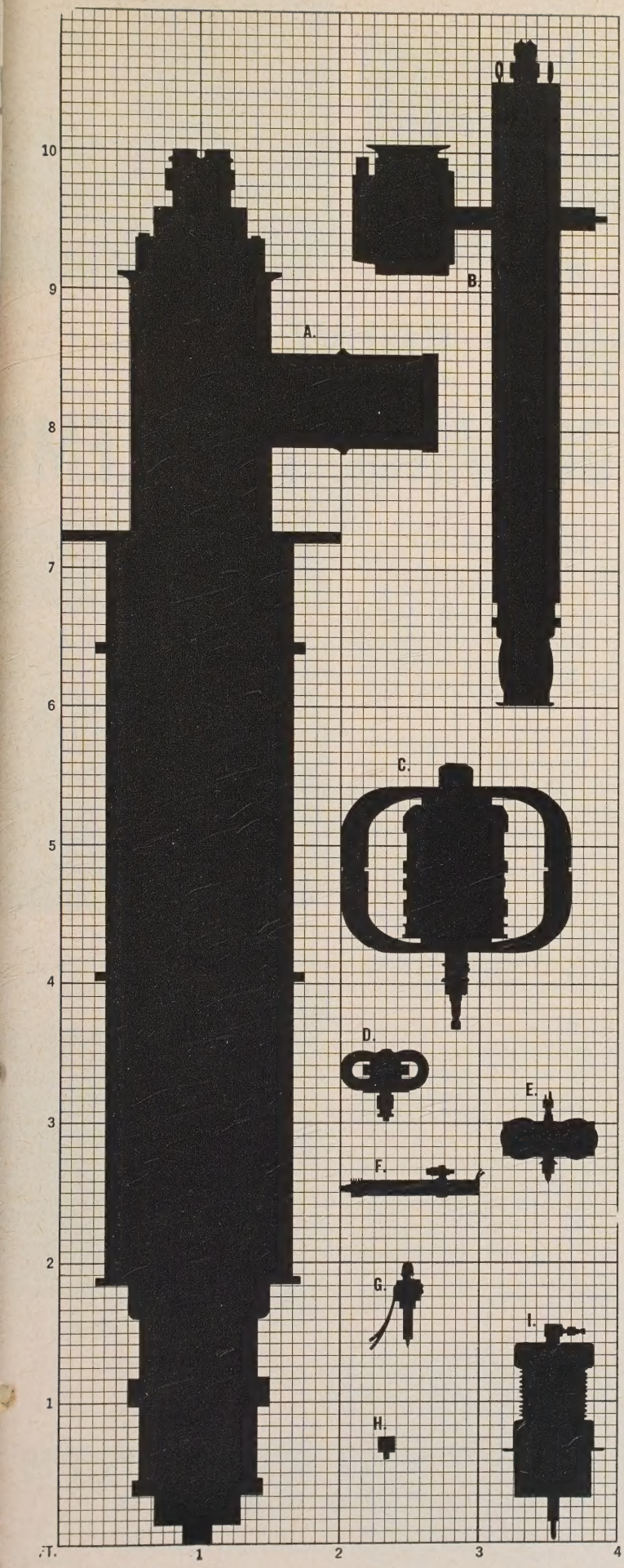


ONE METER TO FOUR MILLIMETERS

New Litton Tubes for Air and Ground Support

A. L-3403 KLYSTRON TUBE: One of our super power pulse klystrons for use in long range space radar detection and tracking.

B. L-3270 BROADBAND KLYSTRON: A 2 megawatt L-band klystron offering long life, high peak power, 8 percent bandwidth. Other broadband klystrons, using the exclusive Litton Skirtron techniques, are available with higher power in the L through S-band region with .002-.004 duty cycles.

C. L-3455 HIGH POWER MAGNETRON: A new magnetron delivering a minimum of 2 megawatts peak power at 406-450 mc. with a .002 duty cycle.

D. L-3458 HIGH TEMPERATURE PULSE MAGNETRON: Provides long life operation at ambient temperatures in excess of 662°F. Many hours of 900°F. operation have been achieved in X-band tests.

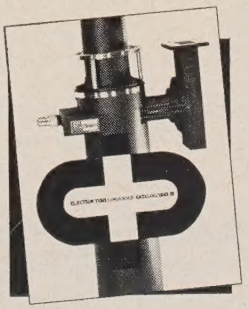
E. L-3629 FLOATING DRIFT TUBE KLYSTRON: High power, water-cooled klystron oscillator fixed tuned at 33,000-37,000 mc. Power output: 15 watts CW minimum. Other tubes available for immediate delivery from 12-4 mm. wavelength.

F. L-3472 TWT: PPM focused traveling wave tube offers higher CW power — 10 watts minimum — and wider bandwidth in a compact 3-lb. size. Operates in the range of 7,000-11,000 mc. One of a line of TWT's including a 1000-watt X-band pulse tube.

G. MICROTRON: The L-3189, one-kilowatt CW magnetron, is accompanied in package form by an electromagnet and filter assembly, high voltage and filament and isolation transformers. Only 6-second warm-up. Two year warranty for domestic microwave cooking.

H. L-3430 CUBE MINIATURE MAGNETRON: A one-kilowatt miniature magnetron, fixed tuned at 9300 ±30 mc, weighing less than 9 ounces and no bigger than a normal X-band waveguide flange. Developments at other power levels and frequencies are planned.

I. L-3408 SWITCH TUBE: Provides switching at relatively low control voltage levels with an efficiency of 95 percent. Features high voltage holdoff, high current handling. Collector ratings: 150 Kv; 20 Amps; 10 KW dissipation.



For information on our tube line, exclusive of classified types, send for the 1962 Electron Tube Condensed Catalog. Write to: Marketing Dept., Electron Tube Division, 960 Industrial Road, San Carlos, California

LITTON INDUSTRIES
Electron Tube Division
MICROWAVE TUBES AND DISPLAY DEVICES

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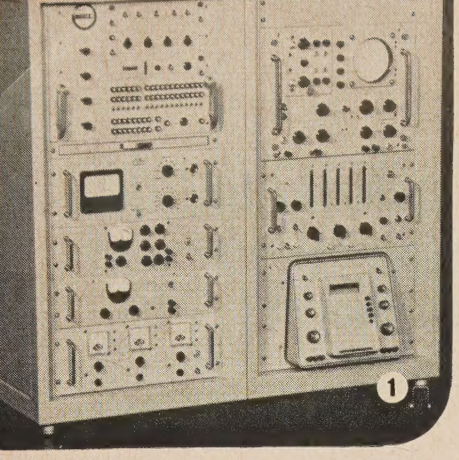
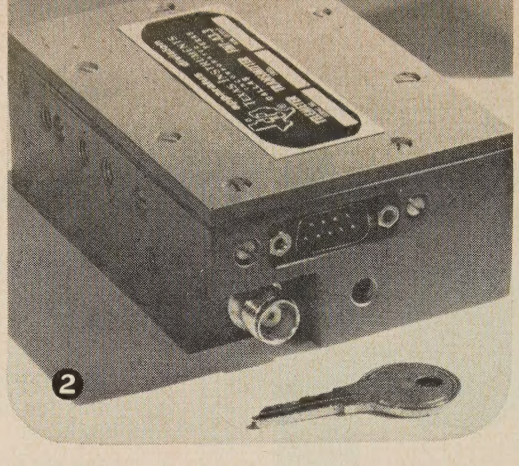
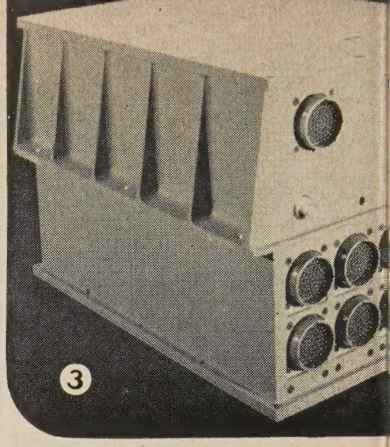
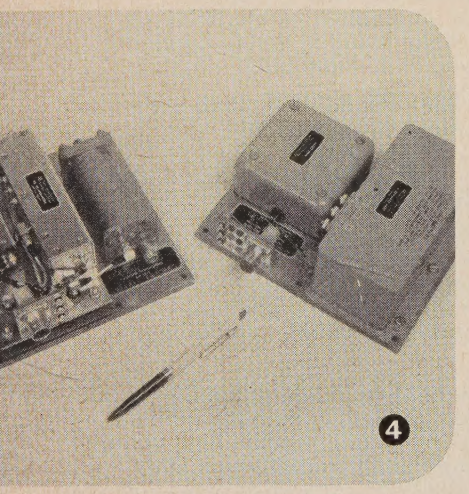




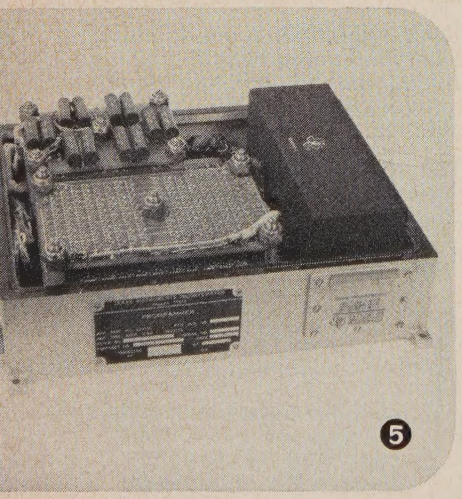


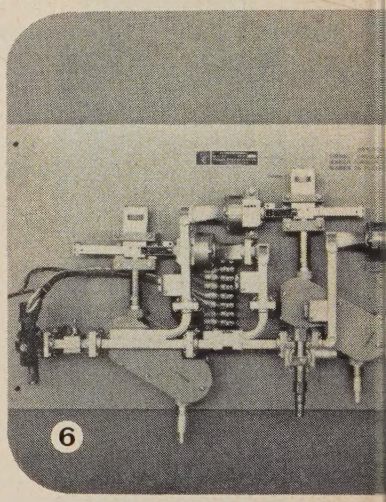
HERE'S HOW TI SOLVES SPACE COMMAND/GUIDANCE PROBLEMS

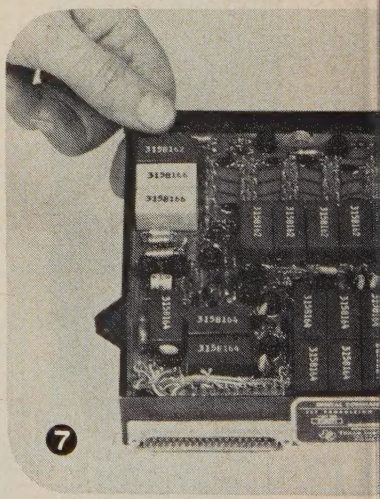


With **experienced** systems engineering staff–**complete** manufacturing capability–**product-proved** research and development laboratories–plus **time-tested** equipments now operational, some of which are:

1. Command System Ground Checkout Equipment for Jet Propulsion Laboratory, California Institute of Technology, to test Ranger 3-5, NASA lunar probe.
2. Solid-State FM/FM Telemetry Transmitters operated in Mercury spacecraft flights.
3. Flight Data Encoder uses high/low-level PCM telemetry system . . . with ±0.5% accuracy, nulled-out drift. A similar 70-channel system has been supplied to Jet Propulsion Laboratory for Mariner A.
4. Solid-State UHF Beacon Transponder made possible missile tracking by MIT Lincoln Laboratories Millstone radar.
5. Digital flight controller/programmer in Douglas Aircraft's Delta Launch vehicle helped orbit NASA weather satellites Tiros II and III, communication satellite Echo I, space probes Explorer X and XII.
6. 3-Channel Parametric Amplifier—Low-noise operation for C-Band monopulse satellite tracker for Bell Telephone Laboratories.
7. Digital Command Decoder for Ranger 3-5 lunar probes.







For information on your specific command/guidance requirements, contact **MARKETING DEPARTMENT.**

APPARATUS DIVISION
PLANTS IN DALLAS
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SOLDER?

FORGET IT! AMP has a **crimp** for coaxial connections

AMP rolled out all 20 years of its initiative in solderless termination techniques to meet the double challenge of coaxial wire termination. The goal: get rid of the solder; get rid of the double danger of burned insulation; get rid of the overtime in labor and costs; and measurably increase reliability.

AMP's new COAXICON* contact line gets rid of the solder. In its place, the COAXICON contact technique gives you the fastest, lowest-installed-cost crimped coaxial wire termination available anywhere in the industry.

One crimp does it — one stroke of an AMP tool attaches a COAXICON contact **simultaneously** to coaxial outer braid and inner conductor.

The COAXICON contact line has remarkable depth, for both single and multiple-connector applications. COAXICON contacts will accommodate the popular sizes of coaxial cables from RG 196/U to RG 62/U having stranded and solid conductors and have a very low VSWR in the KMC ranges when used with cables having a nominal impedance of 50 ohms.

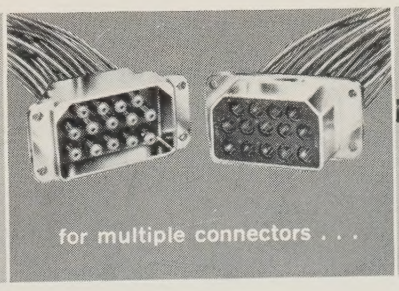
Invite AMP COAXICON contacts to save you time and money on your specific coaxial application.

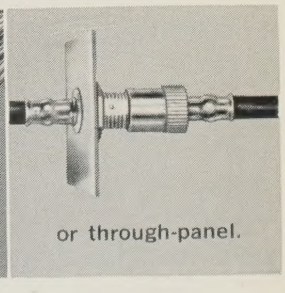
*Trademark of AMP INCORPORATED

AMP
INCORPORATED
HARRISBURG, PA.

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada England • France • Holland • Italy • Japan • Mexico West Germany

One crimp does it . . .


for multiple connectors . . .


or through-panel.

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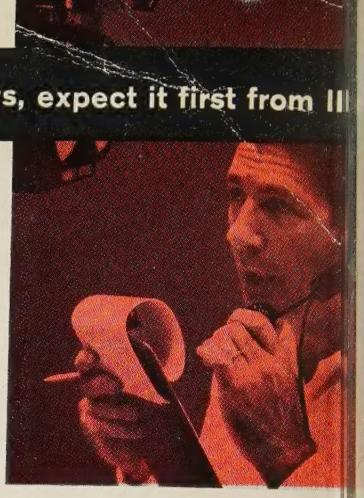
In COMPONENT RELIABILITY : if it's news, expect it first from II



No hold at count-down for resistors of

DOCUMENTED RELIABILITY

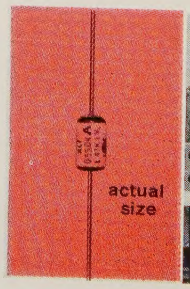
Now available in quantity . . . the resistor reliability developed for Minuteman. New XLT resistor offers proven reliability. The allowed failure rate is 0.0004% per 1000 hours. And a failure is defined as any change of resistance greater than 0.5%.

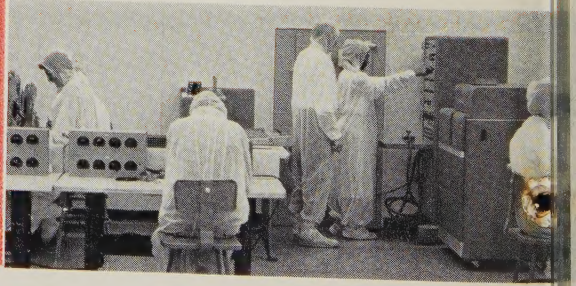
With Documented Reliability, each XLT resistor has an individual punched data card carrying the complete production history of the unit. Subminiature, hermetically sealed, evaporated metal film XLT's are now available for all applications requiring ultrareliable resistors.

A new brochure, "Resistors with Documented Reliability," is now available. For your copy, write to International Resistance Company, Documented Reliability Dept., 401 N. Broad St., Phila. 8, Pa.

CAPSULE SPECIFICATIONS

Power Rating	⅛ W at 125° C, derating to zero at 165° C
Tolerance	± 1%
Resistance range	10 ohms to 100K ohms
Temperature coefficient	±25 PPM/°C, ±50 PPM/°C, ±100 PPM/°C } −55° to +145° C
Type	Evaporated metal film
Construction	Hermetically sealed glass, helium atmosphere
Leads	Weldable (gold-plated Dumet)
Body Length	.281±.030″
Body Diameter	.155±.015″





IRC When Reliability Counts Most

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